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NOVEMBER 1986

COVERING THE BUSINESS OF EMERGING TECHNOLOGY

Special Report

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NEC NEWSCOPE

NEW 32-BIT CMOS MICROPROCESSORS.

The two new members of NEC's CMOS microprocessor V-Series bring unprecedented density and performance in the 32-bit realm. The V60 and V70 supermicros are the first to integrate a Memory Management Unit and basic floating-point processing functions on a single chip.

The V60 has a 16-bit external data bus for an easy, affordable path into 32-bit products while the V70 is a full 32-bit engine designed to power leading-edge systems.

The super-fast V60 and V70 offer a clock speed of 16MHz, and execute 3.5 MIPS and 6 MIPS respectively. A six-stage pipelined CPU enables concurrent execution of up to 4 instructions. With 32 on-board 32-bit general-purpose registers, there is no need to access slow off-chip memory.

The V60/V70 feature an on-chip memory management unit with 4 gigabytes of demand-paged virtual memory space, and 4 levels of memory protection for multi-tasking and multi-user environments.

The V60/V70 instruction set is ideal for high-level languages and OS support (UNIX™ V and proprietary realtime OS). There are 21 addressing modes, 273 instructions, and an emulation mode for 16-bit V20/V30 software.

UNIX: trademark of AT&T Bell Laboratories.

C&C
Computers and Communications

NUMBER 136

COMING SOON: 1.3/1.55μ DFB LASER DIODES.

Dispersion has always been a major obstacle in long-distance, high-speed light-wave communications. With conventional laser diodes emitting multiple spectrums, pulses deteriorate by dispersion after long travel through the fiber. This in turn limits repeater span to 20–30km and capacity to 400–560Mbps for the prevalent 1.3μ fiber optic systems.

NEC has overcome this obstacle with newly-developed distributed feedback (DFB) laser diodes for 1.3μ and 1.55μ fiber optic transmission systems. They feature a stable single longitudinal mode operation, high efficiency and high output power. The new DFB laser diodes are expected to expand repeater span to 80–100km for 1.3μ system or 100–200km for 1.55μ system.

NEC's new DFB laser diodes inherit the renowned double channel planar-buried heterostructure (DC-PBH) and have a diffraction grating in the optical guide region to produce a single wavelength. Output powers are rated 8mw for the 1.3μ NDL5600 and 5mw for the 1.55μ NDL5650. They come in the TO-5 package with an integral monitor photo diode or chip-on-carrier configurations.

As matching light-receiving devices, NEC has planar type InGaAs avalanche photo diodes. They have a selective guard ring construction to achieve high sensitivity and excellent reliability.

NEW INTELLIGENT BUILDING COMPLEX AT VANCOUVER.

The intelligent building is an idea whose time has come. As the perfect nestling for office workers in the Information Age, it centers on an advanced information management system which provides simultaneous voice, data and image services to tenants at less cost while it controls the entire building environment efficiently.

The World Trade Centre/ Pan-Pacific Vancouver Hotel recently opened is just such an installation. NEC's NEAX 2400 Information Management System (IMS) allows tenants to utilize enhanced telephone/facsimile services including least-cost routing, message center and voice mail services, and computer terminal connection via a multifunction digital telephone set. The NEAX 2400 IMS also offers sophisticated services to hotel guests.

NEC's Intelligent Building Systems, based on our unique C&C (integrated computer and communications) technology, are the most advanced and comprehensive available today. As the core of this system, the modular NEAX 2400 IMS can expand to 255 tenant partitions. It supports more than a hundred advanced features including a protocol converter to allow communication with most popular host computers. NEC also supplies comprehensive component equipment including multifunction digital telephones, information display pagers, high-speed facsimiles, business and personal computers, teleconferencing and CATV equipment and local distribution microwave links.

NEC's comprehensive systems breathe new life into the smart building concept, bringing costly services like teleconferencing within the reach of every business.

NEW HIGH-CAPACITY 64QAM DMR SERIES.

NEC's newest 800 Series high-capacity digital microwave radio (DMR) systems transmit two or three DS3 signals per RF carrier, utilizing 64-state quadrature amplitude modulation (64QAM) for effective use of radio spectrum.

Three systems meeting FCC standards are available: a 4GHz 90M-bit system providing 1,344 voice channels, and 6GHz and 11GHz 135M-bit systems for 2,016 voice channels.

The new systems incorporate the latest LSIs, hybrid and microwave ICs throughout to achieve compact design, lower power consumption and improved system reliability. Housed in a standard 19-inch rack, they require minimal cabling work for installation.

The advanced 800 Series is fully compatible with Bell's facility maintenance and administration system.

NEC

EAST KILBRIDE, DEEP IN THE HEART OF SCOTLAND'S SILICON GLEN HAS ATTRACTED MORE U.S. INVESTMENT THAN ANY OTHER SCOTTISH LOCATION.

SO SUCCESSFUL ARE THE U.S. COMPANIES ALREADY HERE THEY NOW EMPLOY NO LESS THAN 20% OF THE TOWN'S TOTAL WORKFORCE, EARNING MILLIONS OF DOLLARS EVERY YEAR.

In 1959, Kraft Foods became the first U.S. company to choose East Kilbride as an overseas location.

Since then, the town has continued to attract more and more companies from the States.

East Kilbride sits in the very heart of Scotland's Silicon Glen.

Within a 50 mile radius there are over 200 electronics companies forming not only a close-knit nucleus of suppliers, but a considerable market too.

As well as being the ideal gateway to the expanding markets in the U.K., East Kilbride is also well positioned for companies wishing to exploit the vast European markets.

Using East Kilbride as a tariff-free springboard, your company has another 600 million potential European customers.

Our labour record is excellent, with 95% of facilities enjoying a strike-free period of five years.

Because 80% of companies are union free, East Kilbride's position as a right to work town is further consolidated.

The town has a proven track record in successfully catering for industrial investment and our range of financial incentives is among the best offered by any area in the U.K.

If your company is considering an offshore project, contact Rick Packer on (617) 431 7474 at PRTM, 36 Washington Street, Wellesley Hills, Massachusetts 02181.

And join the other U.S. companies currently flying the flag in East Kilbride.

NOVEMBER 1986

high Technology

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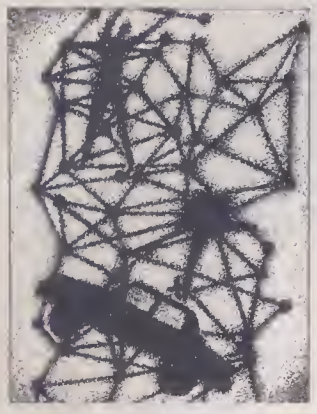
FEATURES

DEPARTMENTS

 HIGH TECHNOLOGY (ISSN: 0277-2981) is published monthly by High Technology Publishing Corporation, 38 Commercial Wharf, Boston, MA 02110, and is intended for persons who hold technology-management and related positions. No subscriptions granted without complete identification, including subscriber name, title, job function, company or organization name, and primary activity of company or organization. Publisher reserves right to determine whether qualified or non-qualified price applies. U.S., U.S. possessions, and Canada qualified rate: 12 issues $30, 24 issues $50, 36 issues $60, payable in U.S. currency. Non-qualified U.S. and Canada: 12 issues $40. All other countries: 12 issues $45, payable in U.S. currency. All subscription correspondence should be addressed to David Patterson, HIGH TECHNOLOGY Magazine, P.O. Box 2810, Boulder, CO 80322, 1-800-525-0643. Please allow six weeks for change of address. Include your old address as well as new and, if possible, enclose an address label from a recent issue. Second class postage paid at Boston, MA, and additional mailing offices. Postage paid at Mississauga, Ontario. POSTMASTER: send address changes to HIGH TECHNOLOGY Magazine, P.O. Box 2810, Boulder, CO 80322.



DAVE RIDLEY

Technology should make life easier for the user, not just the maker

Billions of dollars are spent each year to advance technology. Yet many of industry's products change little in spite of obvious drawbacks. Research and development seems directed more at pushing back exotic frontiers or increasing production efficiency than at making products more convenient for those who must use them.

This provides tremendous opportunities for technically oriented individuals with entrepreneurial spirit. Finding a way of applying technology to improve some widely used product has led to many successful businesses. A few possibilities are mentioned here; further observations from readers would be welcomed.

Big advances have been made in PBX (private branch exchange) technology, offering many new services to users. One can store commonly called numbers for quick dialing, retry numbers busy on the first attempt, get multiple parties on a line, and so on. Yet most offices make little use of some of these services. What is really needed is a way for the system to inform people about features available and how to use them, in a way that helps even the occasional user. Passing a few information sheets around when the system is first installed just doesn't do the job.

Automobiles have become more and more electronic, making troubleshooting increasingly difficult. Yet automakers have not insisted that electronics be designed for easy maintenance and troubleshooting—conveniently interfaced, perhaps, to a personal computer. With the consumer orientation of the Japanese, they may well take the lead in this area. Then they will also probably become leaders in a growing market for troubleshooting systems.

The difficulty of starting outboard motors is legendary, as many thousands of occasional boaters can attest. Not being able to get a motor started when blowing into a rock jetty, or when miles from the dock, can be maddening or downright dangerous. Yet most of today's small motors seem just as touchy as those of decades ago. Manufacturers don't even bother with simple directions on metal plates to help neophytes. Again, inexpensive, efficient outboard motors that start for sure with the press of a button are already being pushed down to lower horsepower ranges by Japanese designers.

Checking in at the airport often means long lines that move at a snail's pace as flight time approaches. Couldn't a bar code be put on prebought tickets so that a quick scan would provide the data that have to be painstakingly punched onto a keyboard for each traveler?

These are just a few places where technology could make life more convenient, and where someone, or some company, might make a lot of money at the same time.

Robert Haavind

highTechnology

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Published monthly by ***High Technology Publishing Corp.,*** 38 Commercial Wharf, Boston, MA 02110.

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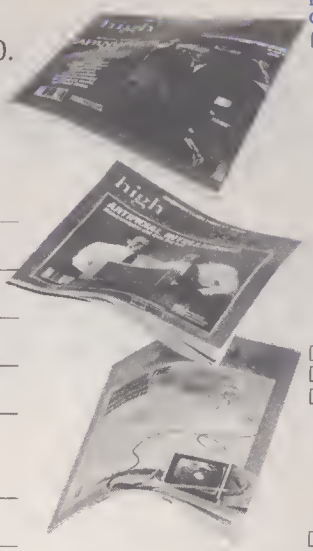

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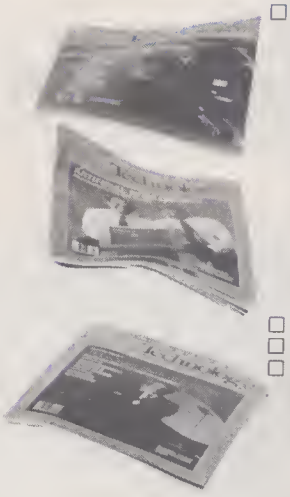

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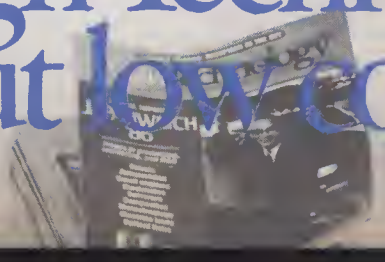

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LETTERS

Japanese information in English

I read your Insights article "Windows on Japan" (Aug. 1986, p. 12) with interest. Even though you mentioned several databases on Japanese technology and business, you did not include the largest English-language source on Japanese technological information in the U.S.—Japanese Technical Information Service. JTIS is fully accessible to U.S. corporations, universities, and government research centers, whereas most of the databases cited in your article are inaccessible due to the language barrier.

Every month JTIS scans over 600 Japanese journals in areas such as biotechnology, microelectronics, computers, and telecommunications to produce some 5000 English-language abstracts. To date, almost 50,000 abstracts have been created.

Herman Baron, Director
Tom Satoh, Manager
Business Planning and Development
Japanese Technical Information Service
Media, Pa.

How the U.S. lost machine tools to Japan

"Designing for flexibility" (Aug. 1986, p. 50), about how the nearly $6 billion Japanese machine-tool industry has achieved world leadership, was well done. Ironically, we in the U.S. were the inventors of the now dominant smaller and more flexible numerically controlled machines, but our lost position in machine tools parallels our downfall in many other areas as well.

The story is well documented in David Noble's book *Forces of Production: A Social History of Automation*. Noble describes our movement into automation as a continuation of the U.S. penchant for overcomplexity, centralized mass production, and tools that admit less and less skill and input by labor.

In Japan, labor organization favored machinist input. The extensive subcontracting systems of the big firms encouraged small-shop use of advanced flexible machining technology. And Japan had no joint military-academic bias for complex systems. Thus Noble reports that "by 1972, 90 percent of Japanese machines were of the simpler design." And today they have the world market!

Tom Peters
Palo Alto, Cal.

Mr. Peters is coauthor of The Passion for Excellence *and* In Search of Excellence.

A leader in bar coding

"Bar codes keep factories on track" (July 1986, p. 64) mentioned Computer Identics and Intermec as being notable participants in the bar code technology field. Accu-Sort Systems has been a leader in this area for almost 20 years and also deserves mention. Some of Accu-Sort's clients include the U.S. Navy, the U.S. Postal Service, and the General Motors Buick plant in Flint, Mich. It is still a privately owned company, while many of the others are public. Nonetheless, Accu-Sort holds a large share of the market.

Robert A. Hollenbach
Account Manager
Zorn Advertising
Chalfont, Pa.

Japanese workers at Okuma Machinery assemble computers for guiding numerically controlled machines.

Dow now

Because I work for Dow Chemical Company in the membranes and separations area, and because Dow is one of Du Pont's competitors, I read your Business Strategy "Du Pont: Moving into membrane filters" (Aug. 1986, p. 14) with great interest. Like Du Pont, Dow has had a commercial membrane device for salt water desalination for many years. While your article mentioned that Du Pont is *considering* devices "to separate the oxygen and nitrogen in air" and "to purify natural gas by removing carbon dioxide," Dow presently markets a product known as Generon for the separation of oxygen and nitrogen in air. Dow also has a commercial business known as The Cynara Company that purifies natural gas by removing carbon dioxide.

D. A. Livingston
Senior Research Engineer
Western Applied Science and Technology Laboratories
Dow Chemical U.S.A.
Walnut Creek, Cal.

Project HOPE: First in health

Your article "Flying eye clinic spreads surgical know-how" (March 1986, p. 68) makes a comparison between Project Orbis and Project HOPE that is inaccurate and misleading. You state that unlike "Project HOPE, Orbis goes beyond immediate care" by supplying donated equipment and hands-on medical training. Project HOPE's primary objective for 27 years has been to provide medical, dental, nursing, and allied health education and training. More than 4000 American educators have volunteered their services in more than 50 countries throughout the world, including the United States, so that we could fulfill that objective.

Our customary program lasts five years, which gives us the opportunity to develop nursing schools, biomedical engineering training centers, learning resource centers, and primary, secondary, and tertiary healthcare specialists in all fields.

We were unique in this effort when we began and continue to fulfill a worldwide need.

John T. Walsh, Vice-President
Project HOPE
Millwood, Va.

We welcome comments from our readers. Please address letters to Editor, High Technology, 38 Commercial Wharf, Boston, MA 02110.

WE WANTED TO SHOW YOU OUR NEW PHYSICS LABORATORY, SO WE ENLARGED IT 15,000 TIMES.

Scientists at AT&T Bell Laboratories have created a "laboratory" on a chip—featuring a functioning transistor only 200 atoms wide.

This new transistor—a laboratory in which microscopic circuits reveal the fundamental nature and behavior of electrons—enables us to explore the physical limits of miniaturization.

Shrinking Pains

Miniaturization is one key to increasing power, capability and speed in an integrated circuit.

But there's more to shrinking a circuit than making it smaller; there are new problems created by the laws of physics. One of the most troublesome is noisy electrons.

Just as electrons can carry information through the transistors of a circuit, they can also make noise. And, as circuits get smaller, noise becomes more of a factor, even to the point of "drowning out" the information.

What's All This Noise About?

To ensure that smaller will continue to mean better, AT&T sought a new way to isolate, understand and control electron noise.

Utilizing an advanced method of precision engraving, chips were carved with the record-breaking 200-atom-wide transistor circuits—so small they force electrons to flow in nearly single file.

This micro-laboratory makes it possible to segregate, manipulate and "tune-in" on individual electrons. (Listening to electrons one at a time is like listening to the clapping of one person in the crowd at the Olympics.) By studying electron flow at this minuscule order of magnitude, AT&T has produced some fundamental revelations about the sources of circuit noise.

The Rocks In The Rapids

As electrons move through the narrow circuit, they behave both like waves and like particles. The particles can be troublemakers. Some produce obstacles in the form of charged atoms—atomic "rocks" that create disruptions in the flow of current, much the way rocks create the "rapids" in a stream.

Noise—in the form of individual "clicks"—comes from sudden changes in current flow as single electrons create and destroy atomic "rocks." Now, using our narrow-channel transistor to study these disruptions in current flow, we are able to identify the individual clicks that comprise data-obscuring noise in ultra-small circuits.

Listening to electrons one at a time.

Quiet! Electrons At Work

Identifying the source of electron noise is a big step toward removing it. But, AT&T is already working on the next step—experimentally altering the nature of atomic obstacles to reduce their effects.

As the number of components on silicon integrated circuit chips continues to increase—by a factor of as much as 100 each decade—a knowledge of noise becomes critical. Today, AT&T packs 2 million components into its megabit memory chip; by the late 1990s, 100-million-component chips should be possible.

A consistent world leader in microelectronics, AT&T will continue to probe the physics of the very small, building on the advanced research made possible by a laboratory on a chip.

☐AT&T publishes a magazine called PROTO, a report to managers on how AT&T technologies are being used in advanced communications products and services.

For a free copy of PROTO, write: PROTO Circulation Manager, AT&T Bell Laboratories, Box A, Room 1L-404, 101 John F. Kennedy Parkway, Short Hills, New Jersey 07078.

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UPDATE

High tech executives in greater demand

After several years of little or no growth, executive employment levels in high technology fields are expected to rise in the coming year and continue rising through the end of the decade, according to a recent industry survey.

High tech companies throughout the U.S., including electronics manufacturers, software publishers, service providers, and telecommunications firms, were polled by Russell Reynolds Associates (New York), an executive recruitment group. Three-quarters of the companies expect to increase overall employment by 20% or more over the next year, and 83% foresee at least some increase. Only 12% anticipate a decrease. Although hiring in certain job categories (planning and corporate development, general management) is expected to decline, the outlook for most categories is promising. In greatest demand will be executives in marketing and sales—areas in which two-thirds of the firms intend to boost hiring—followed by those in R&D and engineering and manufacturing, where 39% expect increases.

Specific reasons for the upswing are hard to pinpoint, according to Dennis Hightower, manager of the Los Angeles office of Russell Reynolds. In all likelihood, he says, industries are simply looking to "brighter days ahead" after the recent recession.

Faster chip enters the PC mainstream

In mid-September, Compaq Computer (Houston) became the first major vendor in an anticipated flood of companies to offer a personal computer based on Intel's new 32-bit microprocessor, the 80386. The computer industry had long awaited the Intel chip, which is the latest advance in the microprocessor line that has become the IBM-backed standard for business PCs; the chip's predecessor, the 80286, powers IBM's high-end PC/AT and a host of compatibles. Compaq claims that its new machine, the Deskpro 386, not only runs virtually all IBM PC software but also offers far more memory and 2–3 times the processing speed of AT-level machines.

The Compaq Deskpro 386 gets most of its speed from Intel's new 80386 microprocessor.

The Deskpro 386 gets its high speed largely from the 80386, which operates on 32 bits of data at a time and runs at a 16-MHz clock rate, instead of the 8-MHz rate of the 80286. In addition, the computer has a 32-bit memory bus—which speeds data transfer within the machine—and can support up to 14 megabytes of internal RAM (versus 1.2 MB for most 80286-based machines). It comes in two models, one with a 40-MB hard disk ($6499) and one with a 130-MB hard disk ($8799).

Compaq expects its latest product to be used in demanding business applications such as complex spreadsheets and large databases—often as a central data repository, or file server, within a local-area network—and in engineering and technical applications such as CAD/CAM. In addition to running the standard MS-DOS operating system, the Deskpro runs the Unix-like Xenix System V/286; a 386 version from Xenix vendor Microsoft, designed to exploit the new chip's architecture, should become available in early 1987.

Ultrasonic motors

A motor driven by ultrasonic vibrations may soon be replacing small electromagnetic motors in video equipment, industrial robots, and other devices. Its developer, Matsushita Electric of Osaka, Japan, claims that the motor is simpler, lighter, and more compact, so it could eventually be manufactured at lower cost. And unlike electromagnetic motors, says the company, the new design runs at low rpm's (500–600), eliminating the need for speed reduction gears.

The heart of the motor is a pair of metal rings or disks, one on top of the other, coated with a specially developed high-friction plastic. The lower ring, the stator, is bound to a piezoelectric ceramic that transfers ultrasonic vibrations to the stator when excited by an electric current. The result is a traveling wave—a series of tiny deformations on the surface of the material—that ripples around the stator's circumference, carrying the rotor with it. The direction of rotation is reversed by changing the polarity of the current.

Ultrasonic motors under development elsewhere have not been efficient enough for commercialization, reports Matsushita. But by cutting notches in the stator to reduce its stiffness and thus permit waves of greater amplitude, Matsushita raised the energy-conversion efficiency to 45%. (By contrast, says the company, reduction gears drag the efficiency of electromagnetic motors to as low as 10%). Matsushita plans to use the motors first in automatic zoom lenses on its video cameras, and will begin supplying them to other manufacturers, probably next year.

Matriculating in space

A small group of astronautical engineers is striving to give new meaning to the term "higher education." Their plan: to found an international space university, with permanent quarters in orbit. "We'd like to gather some of the best students, who are future leaders of technology and science, and educate them together," says group chairman Peter H. Diamandis, an MD-PhD candidate in aerospace engineering at Harvard Medical School and MIT. The ultimate aim is to "provide the next generation of students with the education and motivation to fully develop the space frontier."

The group has some down-to-earth backing. It has raised $11,000 from corporate sponsors and enlisted the aid of MIT president Paul E. Gray and associate engineering dean Jack L. Kerrebrock. Its advisory board also includes Harvard president Derek Bok and former Apollo astronaut and senator Harrison H. Schmitt.

The curriculum has yet to be narrowed down, but "initially we will take a broad look at all the sciences as they apply to space matters," says vice-chairman Kenneth H. Sunshine, an engineer at Draper Laboratory (Cambridge, Mass.). "We'll also consider subjects such as law, sociology, psychology, and medicine that have application to space."

Diamandis plans so start the school in 1988 as a summer session at a host university, probably MIT, perhaps followed by the University of Beijing in 1989. Then, says Diamandis, the project would grow to a year-round institution. In 20 years or so, the university would move into space (most likely by buying a module attached to a space station), allowing students to do research in orbit.

Pacemaker (right) and defibrillator (left), displayed by Cleveland Clinic's James D. Maloney, may soon be merged into a single unit.

Dual implants restore normal heartbeat

For the first time, cardiologists have implanted two separate devices—a pacemaker and a defibrillator—for treating tachycardia (abnormally fast heartbeat). The concept has been picked up by several medical equipment firms that hope to combine the devices into a single lightweight implant within a few years.

More than just an uncomfortable experience, tachycardia may trigger ventricular fibrillation—the uncoordinated quivering of the heart that claims hundreds of thousands of lives annually. Pacemakers, implants that respond to abnormal heart rate by giving the heart a modest electric jolt, restore normal beating in most cases. But sometimes they make the heart pound even faster.

To solve this problem, James D. Maloney, a cardiologist at the Cleveland Clinic, has implanted several patients with an experimental anti-tachycardia pacemaker and a commercial defibrillator. If the pacemaker fails to correct the tachycardia, the defibrillator delivers a powerful shock that usually restores normal rhythm.

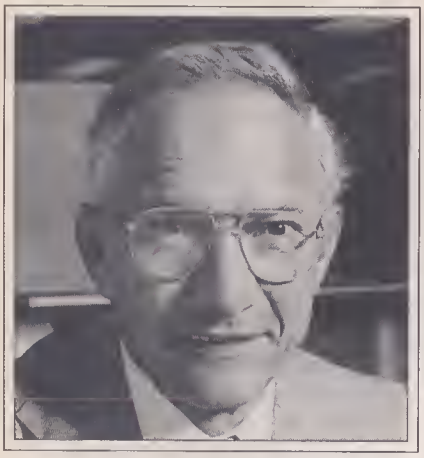
Recent attempts to wed the devices have resulted in a unit measuring five inches square—too big for routine use. "The company that develops a pacemaker-size unit programmable from outside the body will be in the best marketing position," says Maloney. Such a device, he says, could be implanted in as many as 100,000 patients per year in the U.S.

Refrigerating with magnets

Magnets have always been handy for sticking notes on refrigerators, but now they're being used to do the cooling. In refrigerators developed by Astronautics Corp. (Milwaukee, Wis.), magnetic heat exchangers replace bulky compressors, resulting in units that are said to be smaller and lighter than regular refrigerators, as well as 30–40% more efficient.

The new refrigerators exploit the magnetocaloric effect, whereby certain magnetic materials—in this case, gadolinium—heat up in a magnetic field. A piece of gadolinium on a rotating ring spins into the gap between the poles of an electromagnet. Simultaneously, the heat generated is drawn off by a system of circulating alcohol and vented to the outside. Then, as the gadolinium leaves the field, it loses its magnetocaloric energy. Now colder than before, it is used to cool a second fluid system, which in turn cools the refrigeration compartment. The cycle repeats once per second.

The units are claimed to be efficient over a wide temperature range (even near absolute zero, using a fluid such as liquid hydrogen). The company plans to start selling lab models next year. Home units, planned for the '90s, could take over part of a market now estimated at a cool $5 billion.



COURTESY INTEL

Reviving Yankee ingenuity

Robert N. Noyce
Vice-Chairman, Intel Corp.

The notion of the rugged individualist overcoming all obstacles has characterized American cultural history from its beginnings. The same spirit of innovation that brought the first colonists to the New World and later spurred the settlement of the West was also the foundation upon which so many of our key industries were built. All such ventures start with individuals who try to break through conceptual barriers and open the eyes of the world to previously unexplored opportunities.

We in industry certainly don't have to worry about a shortage of innovative ideas—we're still blessed with a great many gifted people—but it's becoming increasingly difficult to maintain environments where those seeds of creative thought can grow. Larger economic issues are having an inhibiting effect. The semiconductor industry in particular has had its troubles over the past couple of years; it's pretty hard to think about extending frontiers through innovation when many companies are struggling to survive.

Without a robust rate of growth, there isn't any "slack"—economic solvency—in the system that allows companies to experiment. The entrepreneurial individual is less likely to innovate if he or she cannot pursue an idea just for the sake of curiosity.

When the slack is removed, failures become critical—they can affect the solvency of an entire company. Under such pressure, it's extremely difficult for creative minds to function. We can't stand over people with a whip and tell them to create, or else! The innovation process is dependent on our ability to give researchers breathing room and leave them alone so that their ideas can eventually bear fruit.

During Intel's first few years, for example, we budgeted significant amounts of money for new projects. We didn't always know what those projects would be, but we knew that we had some pretty good minds in our organization and we had to provide the environment where those people could think and create. That's how Dov Frohman invented the EPROM and how Ted Hoff developed the microprocessor. There was no guarantee that their ideas would work, but we never would have found that out if we hadn't taken the risk and allowed those people to succeed—or, for that matter, fail.

As we now know, they didn't fail. Their ideas changed our industry and, with it, the way people live today the world over. But those two devices appeared in 1971. Things were much different then. There was a general feeling of optimism about the economic future of this country. After all, we had put a man on the moon only two years before, we led in almost all key areas of technology, and our position in the world economy was almost unchallenged.

Now, fifteen years later, we look at our industrial future with a certain pessimism. The slack has largely disappeared. As our economy has tightened, we've put serious constraints on our ability to innovate, not only on the individual but on the corporate level. Increasingly, we find ourselves playing things closer to the vest, not taking the kinds of risks that characterize the big breakthroughs.

Such a pessimistic outlook breeds disorder and mediocrity. During good times, the pie is big enough so that everyone is assured of a substantial slice. But during bad times, groups become more protectionist and less outward-looking. They become concerned only with the issues that affect them directly, and the same number of voices end up clamoring for a piece of a smaller pie. It becomes harder to focus on long-term global issues.

The picture is pretty grim at present, but there are things we can do to turn the tide. I participated not long ago in the President's Commission on Industrial Competitiveness, headed by John Young of Hewlett-Packard, which set forth a number of recommendations. First among them, America must return to one of its most fundamental values: the old "saving for a rainy day" concept. We have become a nation of spenders; one look at the federal budget and trade deficit tells that story. It's axiomatic that if we consume more than we produce, we must import, and that strengthens other economies instead of our own. We end up removing the slack, limiting the role of the individual as an innovator, and ultimately degrading the innovation process at its core.

This trend could have been addressed through appropriate tax reform. Economists usually agree that investments can be increased by taxing consumption and exempting savings. But the recent tax bills are movements in the opposite direction. Taxes would be shifted from individuals who spend, to corporations that invest most of their income. This doesn't bode well for the efforts of industry to put money into new plants and equipment; the system will not allow us to grow.

Trade policy is also critical. Our government has yet to focus on trade as a national priority. Even though somewhere around 15–25% of the manufactured goods we consume are now produced abroad, the belief persists that we are still a domestic economy. The Young Commission recommended that a Cabinet-level Department of Trade be formed to provide a national focus for addressing this issue.

What's more, even though most of our productivity improvements have

This article is adapted from a speech made earlier this year at the annual meeting of the Institute of Electrical and Electronics Engineers in San Jose, Cal.

come from advances in science and technology, we are now falling behind our trading partners in much of this crucial activity. As more of our national research is being devoted to defense—with its questionable fallout effect on commercial applications—our civilian research and development efforts are being shortchanged. The Young Commission recommended that a Department of Science and Technology be formed to assure that our nondefense R&D is supported and coordinated in explicit pursuit of industrial competitiveness.

We must also invest in the education of our present and future work force by supporting our educational system, providing for worker training (and retraining), and improving the relationship between management and labor. Traditional strife must give way to cooperation, without which we will be unable to advance.

We're also going to have to learn how to manufacture better. The Pacific Rim nations have proved rather emphatically that they can make quality products less expensively than we can, and the gap in labor costs is not the only factor. We've gotten sloppy over the years, largely because we never had to worry about competition before. It's time, then, to turn our innovative thinking to manufacturing technology. Process engineering must be raised to the same exalted status that we have bestowed on product design. We also have to work smarter and get more out of the facilities that are online today.

Finally, our corporations must cooperate with each other to increase our national productivity. At a time when competition is global, we must recognize that the threat to our well-being lies not in the cooperation between companies but in the lack of it. By pooling the knowledge and resources of our leading corporations, America can become more competitive.

It's no accident that I've wound up talking about governments, global policies, and large corporate combines in trying to get to the root of individual contributions. Unless the larger issues get resolved, and the climate for innovation becomes affordable, we'll never be able to regain the slack that is so necessary for the individual creative mind to flourish. But if we reestablish that environment, I have no doubt that the individual in our society will once again drive those quantum leaps that have traditionally characterized American industry. □

Intergraph:

STAYING AHEAD IN CAD/CAM

More than a few companies that supply expensive computer-aided design and manufacturing (CAD/CAM) systems have been sent reeling by the continuing stagnation in capital spending, but Intergraph (Huntsville, Ala.) has managed to keep a steady course. In the past two years, it has passed rivals Computervision and GE subsidiary Calma—both of which have stumbled—to move into CAD/CAM's number-two spot, second only to IBM. With 1985 sales of $526 million, Intergraph had 15% of the market (behind IBM's 21%), estimates research firm Daratech, of Cambridge, Mass. The company was able to expand even during an industrywide recession, with a 30% growth rate in 1985 and an additional 20% expected this year (though these figures pale in comparison with the soaring 60% growth rate it posted in 1984).

Intergraph owes its success to "an extremely consistent product strategy," says Robert Grandhi, a technology analyst for Interstate Securities (Charlotte, N.C.). The company made a prudent decision in the late 1970s not to manufacture the computers used in its systems, Grandhi notes, but to concentrate instead on software design. Thus, Intergraph was spared the expense of developing its own 32-bit processors when 16-bit systems became outmoded. And it was relatively unhurt by the deep price cuts that followed the introduction of low-cost engineering workstations in the early 1980s by start-ups such as Apollo. "It's become a difficult business to make money in, with CAD/CAM companies now selling workstations at $25,000 that used to sell for $125,000," says Bruce Johnston, CAD/CAM analyst for First Boston (New York).

In Intergraph's CAD/CAM systems, the same geometric parameters used to design an object also control the final manufacturing process, says manager Jerry Adams.

Intergraph buys almost all its computer equipment from Digital Equipment Corp., adding proprietary components such as file, graphics, and communications processor chips to increase overall system speed. The choice of DEC equipment became a strong selling point for the company, analysts say, because customers can use it to run a wide array of general-purpose software as well as CAD/CAM programs. What's more, Intergraph does not sell any of its several hundred software packages without hardware, a fact that has undoubtedly boosted its profitability. Indeed, it is one of the few "turnkey" vendors left in the CAD/CAM industry, supplying hardware, software, installation, and training, says Jerry Adams, the company's application manager of computer-integrated manufacturing.

Intergraph hasn't been without problems, however, many of them revolving around its recently introduced Interpro 32 workstation, which is based on a 32-bit microprocessor from National Semiconductor. In designing the Interpro, which it developed in response to the growing popularity of low-priced engineering workstations, Intergraph broke precedent and decided to manufacture the hardware itself. (Some analysts speculate that this decision was prompted in part by the delayed introduction of DEC's workstation, the Microvax.) But the Interpro has been plagued by delays of its own, stemming largely from difficulties in converting software written for a proprietary DEC operating system to run under Unix, the Interpro's operating system. Unfinished software caused sluggish sales, and at midyear Intergraph was shipping fewer than 300 units a month, by Adams's estimate, in contrast to expected volumes three times that amount.

Future trouble may come from another quarter, however. The latest newcomers to the CAD/CAM market, makers of systems based on PCs, are expected to become a more serious threat with the anticipated introduction of powerful new PCs from IBM and Apple Computer. Intergraph contends that it doesn't compete directly with makers of PC-based systems, but sells instead to a more technically sophisticated part of the market. "The key to our systems is integration," says Adams. "We give true 3-D modeling, and the geometry of an object controls the

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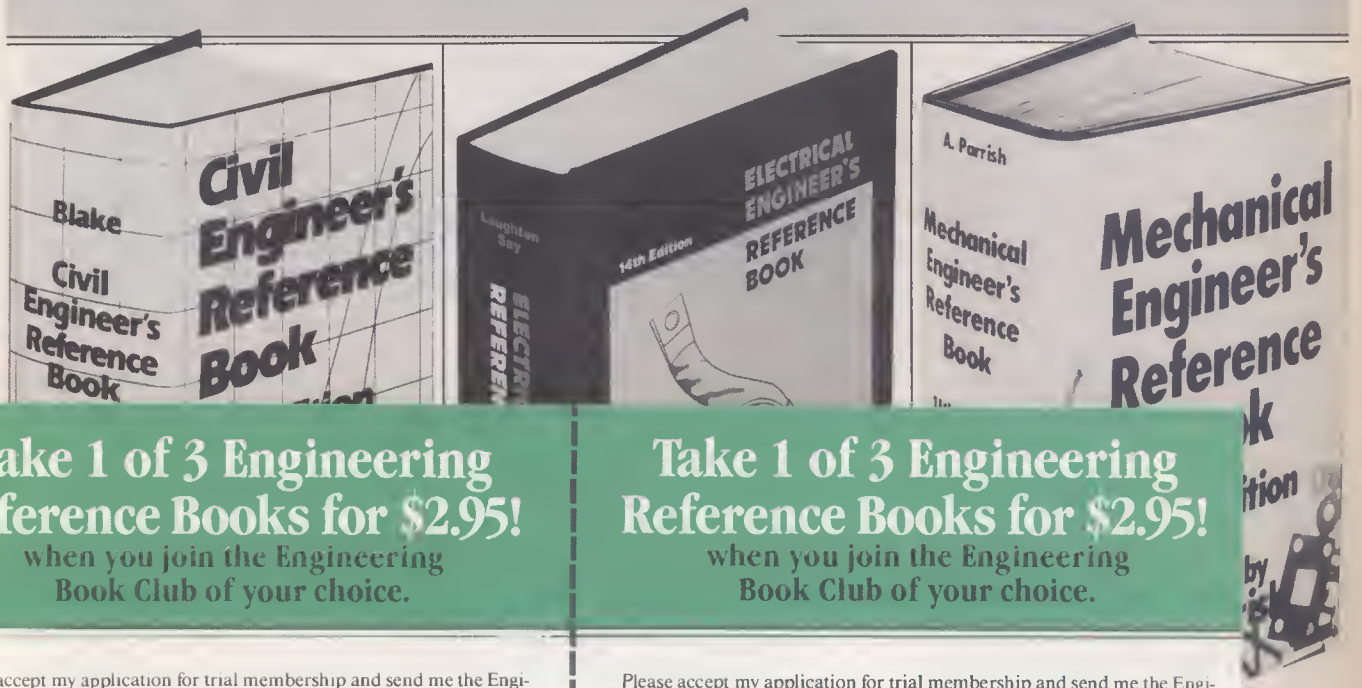

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BUSINESS STRATEGIES

Intergraph:
STAYING AHEAD IN CAD/CAM

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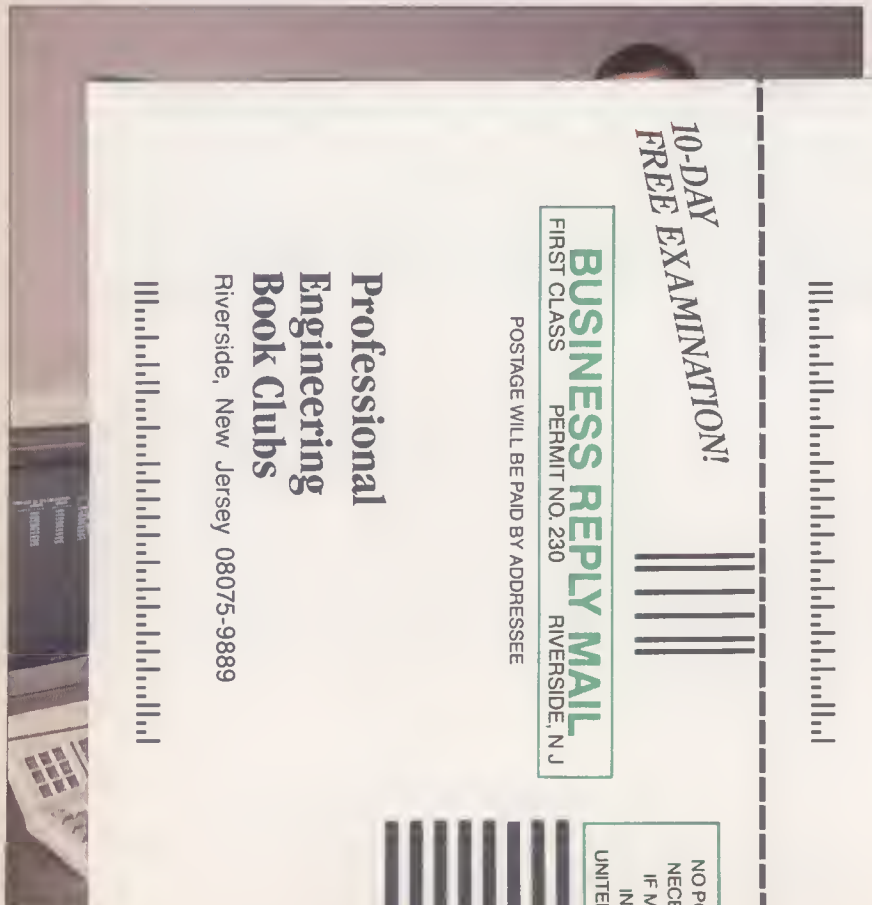

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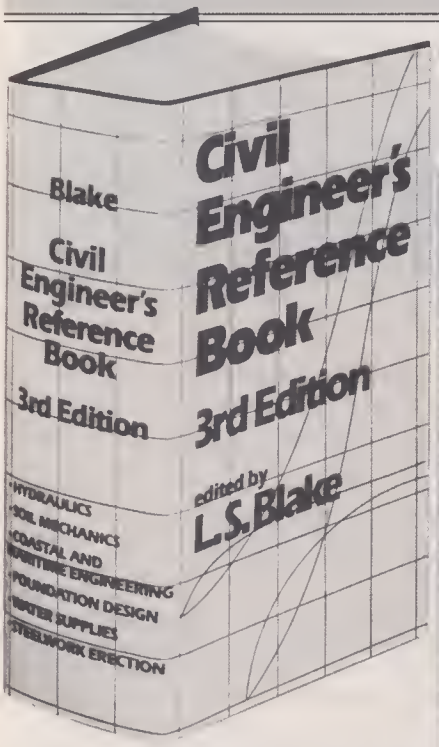

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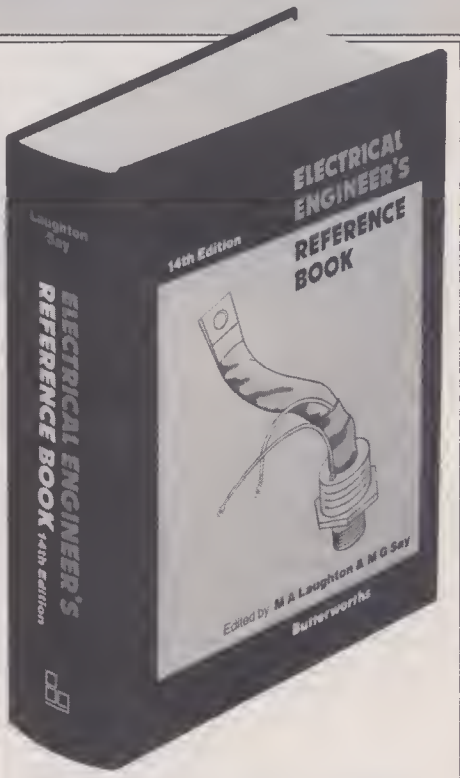

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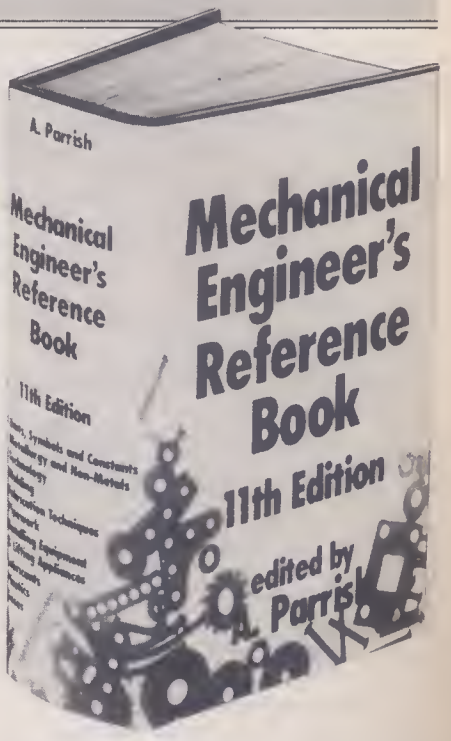

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[design and manufacturing] process all the way to the end product."

At the high end of the market, Intergraph finds itself in head-to-head competition with IBM, especially in the mechanical design segment, which the computer giant dominates. While IBM's size lets it price aggressively, many observers believe its software—which is purchased from independent developers—is inferior to Intergraph's. Intergraph is continually adding improvements, says Interstate's Grandhi, as in the case of a technique called object-oriented programming that allows it to add program features with little modification of old code. This will enable Intergraph's systems to interact with other companies' equipment without extensive reprogramming, proving once again, he believes, that the company is "at the forefront."

—Robert Snowdon Jones

JOSEPH MCNALLY

Microsoft's CD-ROM project, still in the R&D phase, won't begin generating revenues until 1988, estimates company chairman William Gates.

Microsoft: USHERING IN THE CD-ROM ERA

One of the country's most diversified microcomputer software publishers, Microsoft (Redmond, Wash.), is laying the groundwork for what it hopes will become yet another lucrative area: supplying software for use with optical discs. Compact disc read-only memory (CD-ROM)—so called because it uses the same discs and playback mechanisms as digital music players—is being heralded by many computer industry trend spotters as an important new data storage medium. Despite drawbacks (for instance, there is no effective way to erase and rerecord CD-ROMs), the discs have enormous storage capacity compared with conventional magnetic media. Consequently, they are already appearing in a number of new applications that use vast quantities of prerecorded data, such as electronic encyclopedias and reference catalogues.

From the start of Microsoft's involvement two years ago, CD-ROMs appear to have been a pet project of company founder and chairman William Gates. The CD-ROM division "is the only group at Microsoft that reports directly to me," he says, even though "it is really an R&D activity for now," with no revenue projected until 1988 at the earliest. Given the healthy state of the company's finances, though, it can afford to indulge in long-term projects. Best known as the supplier of the operating system for the IBM PC and its clones, Microsoft also sells an assortment of PC application packages. It logged $39 million in profits on $197 million in sales for the year ended in June, in addition to the $39 million in capital the company raised when it went public last spring.

By its own account, Microsoft has been spending heavily on CD-ROMs, in large part to help launch them into the market. To iron out incompatibilities among different manufacturers' hardware, the company was instrumental in devising a data file format that has already been adopted by Sony and Philips. And on its own, Microsoft held an industrywide conference last March to "generate some activity" among software developers and information providers, says Thomas Lopez, Vice President in charge of the company's CD-ROM division. Such activity, Microsoft hopes, will create demand for two products currently in the works: software that links CD-ROM drives to personal computers, and software development tools that application writers can use to add the graphics, audio, and video features made possible by the discs' vast storage capacity.

Few of the 60 or so commercially available CD-ROM applications that already exist—for the most part, unaltered versions of databases that were previously available on line or in print—take advantage of these capabilities, says James Porter, president of Disk/Trend (Los Altos, Cal.). But he predicts that the multimedia approach will be embraced wholeheartedly by makers of educational films and training materials. A number of small companies, such as start-ups Interactive Training Systems and Visage, have already entered this field.

But even conventional text-based applications can benefit from features made available by CD-ROMs, claims Lopez, because "there's so much available real estate, you can use it in ingenious ways." For instance, a computer company using a disc to hold an entire bookshelf's worth of operating manuals might also devote space to storing separate, special-purpose indexes for end users, maintenance technicians, and software developers. Such versatility, says Lopez, will make CD-ROMs "the information distribution medium of the 1990s."

That may be wishful thinking, cautions Raymond Freeman, president of management consulting firm Freeman

and Associates (Santa Barbara, Cal.). While forecasting "strong growth" for the new medium, he predicts that fewer than 500,000 optical disc drives will be shipped in 1991—a minuscule proportion of the installed base of personal computers. Gates, for one, is considerably more optimistic. "Applications like commercial catalogues—some of them pretty widespread—will be appearing in the next few years," he maintains, hinting that Microsoft may have more details about such projects than it's willing to publicly share. "We have already decided on the applications we want to get involved in," says Gates, "and are choosing the partners we want to work with." ***—Sarah Glazer***

Spire:

GaAs FROM GAS

Gallium arsenide (GaAs) is increasingly in demand as a semiconductor material because some of its properties, such as transmission speed and radiation resistance, are far superior to those of silicon. But the material is expensive and difficult to produce. GaAs is made from two relatively rare elements and requires extremely delicate processing techniques to create uniform crystal structures. Uniformity is of the utmost importance, especially if the material is used for complex integrated circuits, since one badly placed defect caused by an imperfect crystal lattice could disable an entire chip.

Spire (Bedford, Mass.) is one of the few companies in the U.S. currently selling equipment for the production of GaAs wafers. Its machines, priced at $150,000–$500,000, are based on a technique called metalorganic chemical vapor deposition (MOCVD), in which gases released into a reaction chamber form layers of crystals on heated wafers. By regulating the gases with computer-controlled valves, these reactors make it possible to control crystal growth quite precisely. And by changing the gases used—sometimes depositing them in alternating layers—it is possible to create a wide range of crystalline substances, such as gallium aluminum arsenide and indium phosphide, with varying chemical and electrical properties.

Founded in 1969 as a weapons research contractor, Spire now has 45% of the domestic market for MOCVD equipment, estimates Steven Ricketts, an analyst for VLSI Research (San Jose, Cal.). Its customers for reactors and processed wafers include IBM, Hughes Research, Siemens, and other major manufacturers of computers and defense equipment. Although only a handful of competitors (such as Crystal Specialties and Emcore) make similar machinery, Spire faces stiff competition from another direction: companies that use alternate technologies to produce GaAs wafers.

One of these techniques, molecular beam epitaxy (MBE), is quite similar to MOCVD in that crystal layers are built up on wafer substrates. However, in MBE systems, heated streams of elements controlled by mechanical shutters are directed onto the wafers. MBE systems are significantly more expensive because of the complexity of the shutter systems. MOCVD reactors, by contrast, require more elaborate safety equipment, since one of the gases that must be prevented from escaping their reaction chambers is arsine, the gaseous form of arsenic.

Another competing method, more akin to producing conventional silicon material, uses furnaces to grow far larger GaAs crystals, which can then be sliced into individual wafers. Roger G. Little, Spire's president, contends that the layering techniques of crystal growing, known as epitaxy, result in material with fewer defects. Others in the industry disagree, however. Technical advances are making it possible to produce extremely uniform crystals using the furnace method, says Mehmet Rona, a semiconductor analyst for Arthur D. Little (Cambridge, Mass.). Epitaxy, he believes, will someday be used mainly for complex materials such as gallium aluminum arsenide (GaAlAs).

Meanwhile, however, Spire is developing a dual-chamber reactor that greatly speeds the production process by allowing a fresh batch of wafers to be loaded while another is being coated. The company does not seem concerned that major Japanese makers of semiconductor manufacturing equipment have developed their own GaAs production machines. The Japanese are "playing catch-up" in the development of MOCVD equipment, says Little. Spire already has projects under way for further improvements of its own, he says, such as growing uniform gallium arsenide crystals on imperfect substrates and developing new semiconducting materials. Spire hopes projects like these will keep it a serious contender for some time to come.

—Patricia Hittner

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Four Tigers of the Orient

Stalking world markets

Asian high tech action isn't limited to Japan: Four rapidly developing nations in particular—South Korea, Taiwan, Hong Kong, and Singapore—hope to expand their roles in global markets. Already serving as major manufacturing sites for Japanese, American, and European companies, the Four Tigers are now beginning to design their own products and provide unique services.

To assess their progress, editors from HIGH TECHNOLOGY recently visited these countries. They discovered that although styles, assets, and problems vary from place to place, all four share an intensity of effort and a strong commitment to entrepreneurship. As the following reports indicate, these contenders plan to build strong economies based on emerging technologies. Their strategy: to combine their own resources with what they've learned from overseas.

SOUTH KOREA

GEORGE MITCHELL/BLACK STAR

TAIWAN

DAVE BARTRUFF

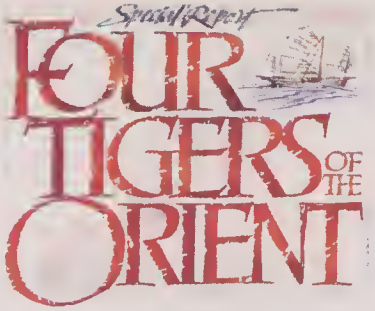
SINGAPORE

DAVE BARTRUFF

HONG KONG

ROB BROWNE

Special Report



SOUTH KOREA: Giants drive development

Seoul—The parking lots of the huge international hotels here are jammed these days with brand-new Korean-made automobiles, each one with a chauffeur who waits patiently while his businessman boss concludes yet another deal with visiting executives from overseas. The cars are a highly visible sign that South Korea is catapulting into the 20th century. No longer merely a maker of cheap shirts and basic steels, this "land of the morning calm" is embracing high technology in a desperate attempt to become a developed nation by the turn of the century. "We'll overtake Britain in less than 20 years," claims Yu Hee Yol, director of technology transfer in South Korea's powerful Ministry of Science and Technology (MOST).

South Korea's recent economic progress has in fact been remarkable. Thirty years ago the country was still reeling from the effects of a devastating war. In 1962 the per capita gross national product was a mere $80, and the World Bank regarded the country as a poor prospect for investment. Today the per capita gross national product is around $2300. That's still about one-eighth the level of the U.S., but Korea's buoyant economy continues to grow by more than 7% annually, one of the highest rates of any newly industrializing country.

Such impressive growth will continue through Korea's next five-year plan (due to start in 1987), says Yu, and much of the growth will be in high tech industries. "We intend to concentrate on high technology business areas with a high return on investment," he says. In particular, the government has targeted microelectronics, telecommunications, automobiles, pharmaceuticals, and new materials as the five most important business areas for Korea. Given the country's authoritarian regime, the business community is virtually certain to follow.

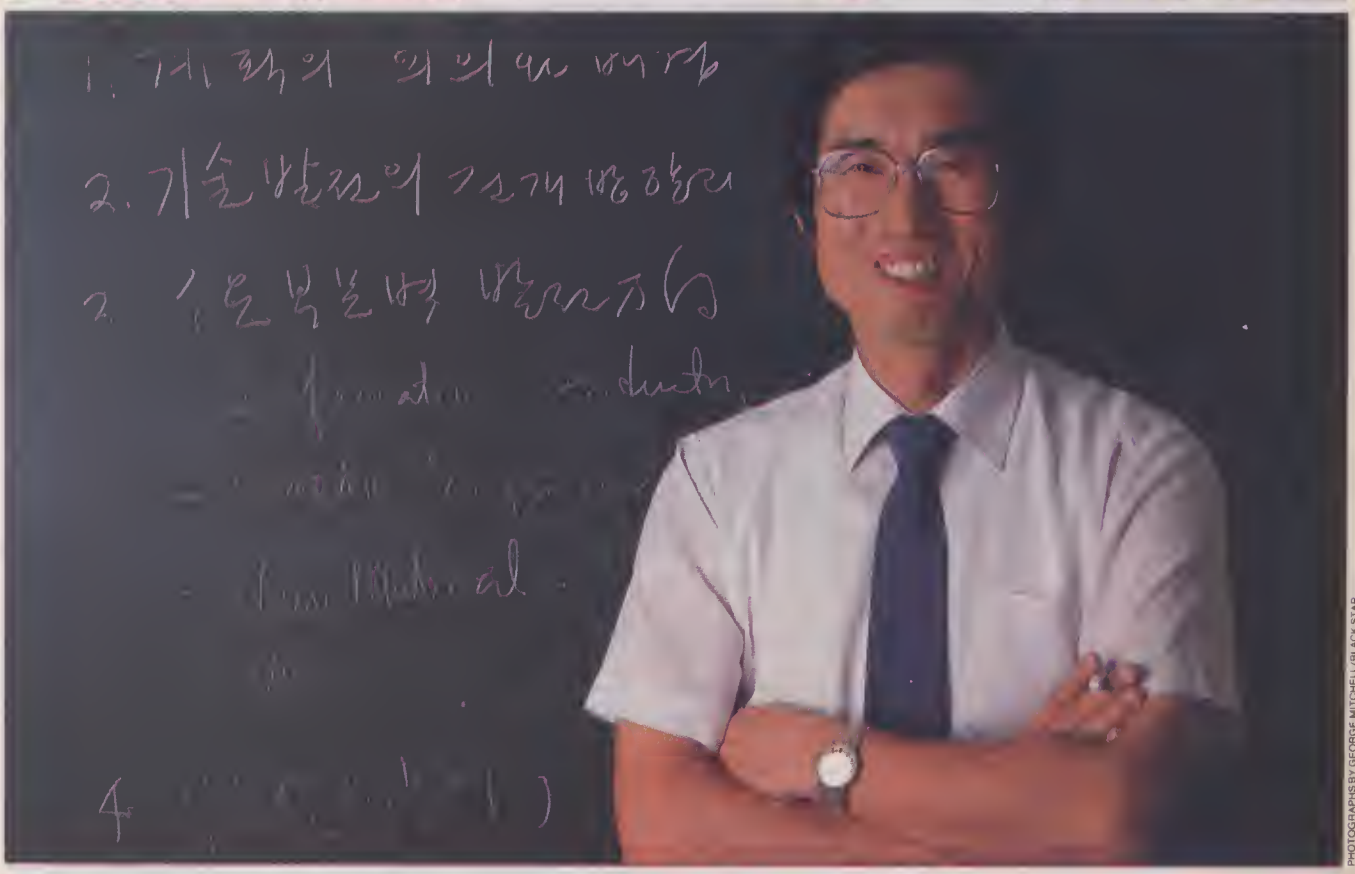
by Jeffrey Bairstow

Indeed, Korean business is dominated by some five giant conglomerates, called *chaebols*—Daewoo, Hyundai, Lucky-Goldstar, Samsung, and Sunkyong—with close economic ties to the government. They have total sales of close to $50 billion, or more than half the country's GNP, and employ nearly half a million people. They manufacture everything from steel, machine tools, chemicals, and textiles to such high technology products as televisions, videocassette recorders, personal computers, semiconductors, and telephone equipment. The *chaebols*, like Japan's massive trading houses, are also active in insurance, banking, securities, and even tourism. Unlike the U.S., Korea has virtually no antitrust regulations that could limit the *chaebols*' operations; in fact, their relationship with the government and easy access to capital funding often enable them to be the first among Korean companies to enter new markets, as Goldstar has done with televisions and VCRs and Daewoo with telecommunications. The chief executives of the *chaebols* meet regularly with government ministers and other officials to discuss the country's economic goals. In return, the government ensures that capital loans are available from the Korea Development Bank (a government agency) for new ventures by the *chaebols*.

To speed its transition to high technology from a dependence on basic industries—for example, steel, shipbuilding and textiles, which continue to be very important for Korea—the country has a consuming need both for sophisticated technologies, such as semiconductors and bioengineering, and for experienced technologists and support staff. "We know that we do not possess the resources to develop our own technologies in all the selected areas," says MOST's Yu. "So we must import the necessary technologies from Japan, the U.S., or Western Europe."

Korea's neighbor Japan continues to be the most important source of technology licenses for Korean business—more than 1500 agreements in the last decade. However, Japan is becoming concerned about a "boomerang effect" and is increasingly reluctant to transfer new technology, particularly in consumer electronics such as VCRs and compact disc players. As Japanese businessmen see Korean companies starting to compete directly, they have begun to withhold technology agreements, forcing Korean companies to buy components from Japan rather than the technology to make the components themselves.

Indeed, there can be little doubt that the Koreans do intend to compete head-on with the Japanese in high technology products. "With U.S. technology and our low-cost, hard-working labor," says Yu, "we could beat the pants off the Japanese." Already, the recent rise of the yen is allowing Korean manufacturers to undercut the Japanese in some world markets. Hyundai has become the leading auto importer in Canada and is beginning to develop markets in the United States. Daewoo recently concluded an agreement with General Motors to make a small car for Pontiac. Kia Motors has agreements with Ford and Mazda to make a "world car" for possible export to the United States. The Korea Development Bank



PHOTOGRAPHS BY GEORGE MITCHELL/BLACK STAR

estimates 1986 exports of automobiles will reach $1.25 billion, about twice the value of 1985 exports.

The Koreans are also looking toward Europe for badly needed technology transfers; recently, President Chun Doo Hwan visited England, France, West Germany, and Belgium to discuss technology cooperation.

In a much smaller way, Korea hopes to export its own technology as well. The Korea Advanced Institute of Science and Technology (KAIST) and Poongsan Metal Co. have licensed a new material they recently developed—a copper alloy for integrated circuit leads—to West Germany's Stollberger Metallwerke. KAIST and Kolon Chemicals have obtained overseas patents for a novel method of making ara-

Top: "We intend to concentrate on high technology businesses with a high return on investment."—Yu Hee Yol, director of technology transfer, Ministry of Science and Technology. Bottom: "Korea hopes to produce 12,000 graduate engineers and scientists a year by the turn of the century."—Lee Chong-Ouk, head of technoeconomic research, Korea Advanced Institute of Science and Technology.

DAVE BARTRUFF

Right: "The challenge of handling a booming $150 million company are more than I ever dreamed of in the U.S."—Park Sung-Kyou, executive vice-president, Daewoo Telecom. Below: From the capitol building in the heart of downtown Seoul, Korea's powerful ministries pursue a five-year plan that pushes the country's giant corporations to invest further in high technology.

GEORGE MITCHELL/BLACK STAR

mid pulp (a synthetic substitute for asbestos) and expect to announce license agreements shortly.

KAIST, a government- and industry-funded research center and a graduate school for scientists, has strong research programs in chemical engineering, semiconductor materials, ceramics, CAD/CAM, robotics, and nuclear engineering. Although its main functions are to train researchers and transfer appropriate technology to Korean companies, it has a technology assessment group that actively promotes Korean technology overseas, mainly in Southeast Asia.

Last year, KAIST produced 500 post-baccalaureate scientists and engineers (most with master's degrees). Another 1000 technical graduate degrees were granted by Korean universities. But Korea needs to produce many more skilled scientists and engineers to complement its labor force if the country is to make progress on its own in high tech industries. "Today we have maybe eight research and development workers per 10,000 employees," says Lee Chong-Ouk, head of KAIST's technoeconomic research group. "Our goal is to have 30 per 10,000 by the year 2000"—comparable to other developed nations. Recognizing the acute shortage of qualified people, the government is funding an ambitious program to produce 12,000 graduate engineers and scientists a year by the turn of the century. "Even so, we'll need another 3000 annually from overseas," says Lee.

Until a few years ago, the traffic in Korean scientists and engineers was all one-way, mostly to the U.S., where many stayed after completing advanced degrees at MIT, Stanford, and other large universities. But the recent growth in the Korean economy has encouraged many bright and experienced nationals to return home, where the salaries are smaller but the challenges are often greater. Choi Min-Sung, a former IBM staff engineer, returned to Korea in 1984 to become director of Goldstar Semiconductor's research laboratories. He was put in charge of setting up a fabrication line that initially produced 64k random-access memories and is currently producing 256k units. "It would have taken many years to get that much responsibility at IBM," notes Choi. His responsibilities may soon increase even further: Goldstar recently signed an agreement with Advanced Micro Devices (Sunnyvale, Cal.) to develop and make 1-megabit memory chips.

Park Sung-Kyou returned to Korea in 1978 armed with degrees in electrical engineering from MIT, Northeastern, and the University of Texas. Today, at 46, he is executive vice-president of Daewoo's Telecom subsidiary, a telephone and computer equipment maker that has boomed from $3.5 million in sales in 1980 to more than $150 million (estimated) this year. "Yes, there are salary differences and six-day work weeks," he says, "but the challenges of handling a company of this size—with both a growing domestic market and a highly competitive export market—are more than I ever dreamed of in the U.S." Park was responsible for the development of the IBM-compatible computer that is marketed in the U.S. as the Leading Edge series.

Park, who has started numerous in-house training programs, also makes several trips a year to the U.S. to recruit Korean computer and telecommunications engineers. But his frequent overseas trips often have a more immediate purpose: to buy or license technology. "We have agreements with both Japanese and U.S. companies—Fujitsu and Sanyo for computers and peripherals, Northern Telecom and General Datacomm for communications equipment—and are discussing similar agreements with European manufac-

TALLYING THE TIGERS

KEY ECONOMIC INDICATORS, 1985	S. Korea	Taiwan	Hong Kong	Singapore
Area (sq. mi.)	41,176	13,814	404	239
Population (millions)	41.1	19.2	5.4	2.6
GNP ($ millions)[1]	83,075	60,078	34,100	17,731
Per capita GNP ($)	2,032	3,142	6,285	6,519
Unemployment	4.0%	2.9%	3.2%	4.9%
Industrial production change[2]	4.4%	1.2%	6.0%	−7.8%
Consumer price index change	2.5%	−0.2%	3.2%	0.7%
Exports ($ millions)	30,283	30,717	30,183	22,806
Export change[2]	3.5%	0.9%	6.6%	−2.3%
Exports to U.S. ($ millions)	10,754	14,770	7,404	4,826
Imports ($ millions)	31,136	20,107	29,704	26,278
Import change[2]	1.6%	−8.4%	3.6%	−5.4%
Imports from U.S. ($ millions)	6,489	4,747	2,810	3,988
Balance of trade	−853	10,610	479	−3,472
Prime rate	11.4%	7.1%	8.3%	7.2%

[1]All monetary figures given in U.S. dollars. [2]Changes are relative to 1984.

Source: International Trade Administration, U.S. Dept. of Commerce

turers," he says. "About half our products are made under license today, and we expect that proportion to stay the same for a long time."

Nonetheless, Daewoo Telecom is plowing back 10% of its revenues into research and development, with particular emphasis on fiber optics and personal computers. That percentage exceeds the rate of R&D spending among many high technology companies in the United States. Similarly, Samsung Electronics Co. (SEC), Korea's largest electronics exporter, is increasing its R&D investment to 9% of sales, or close to $200 million, according to president Han Hyung So.

At present, about 85% of SEC's revenues are derived from consumer electronics goods sold mainly under other brand names, but Han intends to make the Samsung name as well known in consumer electronics as Sony. Although many Korean companies began by manufacturing for well-known U.S. companies, such as Sears Roebuck, executives like Han believes their products can now stand on their own and match Japanese products in both price and quality. Already, SEC manufactures television sets and microwave ovens under the Samsung name in the U.S (Saddlebrook, N.J.) and in Europe (Estoril, Portugal).

But South Korea is not without its problems. Most fundamental is the country's unpredictable enemy to the north—the communist nation of North Korea, with the world's seventh largest army (more than 800,000 strong in 1984). Although South Korea devotes some 6% of its GNP to national defense and the United States still maintains a considerable presence, many South Koreans still fear invasion.

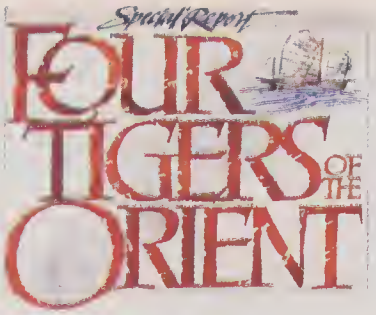
Military concerns aside, as South Korean goods find their way into more export markets, a possible rise in protectionism in the developed nations could slow the country's rapid growth. And South Korea's political climate is already showing signs of instability. Student and labor activists stage frequent and sometimes violent demonstrations in Seoul and have threatened "urban and guerrilla warfare" if full democracy is not instituted by 1988. There are some indications, according to Korean political observers, that President Chun's ruling Democratic Justice Party is prepared to amend South Korea's authoritarian constitution and permit limited elections before the end of his term in 1988. Many experts feel that the 1988 Summer Olympics, to be held in Seoul, will provide a considerable incentive for the government to show the country to be stable and healthy, both economically and politically.

South Korea is also carrying a huge burden in foreign debt: $47 billion. However, Hong Kong banking analysts expect Korea's overseas credit needs will level off at $50 billion. In June the Korea Development Bank (KDB) unexpectedly decided to postpone taking out a $500 million loan in order to wait for more favorable interest rates. Shortly thereafter, officials began to predict an overall trade surplus for 1986, the first in South Korea's history. Exports were up as much as 20% for the first six months of 1986 and may show an increase of 25% (over 1985) by year's end, say KDB officials. If Korea can maintain a favorable balance of trade, the nation's borrowing requirements will decline and foreign lenders will offer better rates.

The KDB has long been a major financing arm for the *chaebols*, ensuring that the giant companies had funds for developing businesses in line with government priorities. And in response to the government's recent recognition that smaller companies have an important role to play in developing high technology industries, the KDB has formed a new subsidiary, the Korea Technology Finance Corp., to provide venture capital loans to small and medium-size businesses. The new agency complements the Korea Technology Development Corp. (KTD), a joint industry–government institution that not only provides financing to high tech start-ups but also offers technical and administrative advice and, most important in South Korea, assistance in dealing with government agencies. More than 50 new companies have been formed with KTD's help, says Kim Chang-Dal, president of the agency. Most of these new companies are expected to develop technologies themselves rather than license them from overseas.

South Korean businessmen and government officials admit that the country still has a long way to go in its efforts to catch up with the developed nations. But the country appears ready to make the effort. In a recent speech, Daewoo founder and chairman Kim Woo-Choong contrasted the great strides made by Korea in the last two decades with the accumulated technology of the industrialized nations: "If our level of diligence only matches that of people in the West, we will never catch up. So we must work harder." □

Special Report



TAIWAN: From imitation to innovation

by Herb Brody

Taipei—Taiwan rode to its present state of prosperity on the backs of an inexpensive and largely unskilled work force. Exports of textiles, shoes, wigs, plastic flowers, and countless dime-store trinkets have paid off handsomely, at least by East Asian standards. But the country (which still tenaciously calls itself the Republic of China despite that name's almost total lack of diplomatic recognition) is finding itself unable to compete on the basis of cheap labor alone. Hungrier neighbors, such as the Philippines, Malaysia, and archenemy mainland China, offer lower manufacturing costs, and jobs migrate inexorably to the lowest bidder.

In response, Taiwan is attempting to forge a new economy based on advanced technology—with local companies beginning to design, produce, and market their own proprietary products rather than manufacturing somebody else's. Taiwan plans to exploit assets it accrued during its years as a manufacturing colony of the United States and Japan. Principal among them is the country's ability to produce large quantities of high technology staples like transistors, printed circuit boards, and computer terminals; the local abundance of such hardware has permitted rapid and low-cost production of a vast array of electronic goods. But now "it's crucial that the country get out of the responsive mode and start controlling its own destiny," says Jerry Wasserman, a vice-president at Arthur D. Little (Cambridge, Mass.), the consulting firm hired to guide the Taiwan government through its industrial upgrade.

The showcase of Taiwan's new policy is the Science-Based Industrial Park, opened in 1980 under the direction of the National Science Council. Located in Hsinchu, about an hour's drive from Taipei, the park offers inexpensive factory space, proximity to two strong technical universities (Tsinghua and Chiaotung) as well as to a national laboratory, and spacious surroundings that contrast dramatically with Taipei's cramped, motorcycle-clogged streets. As of July, 53 companies were operating in the park, and another 13 had been approved for admission.

A would-be park tenant must satisfy several criteria. Probably most important, the company must do R&D, rather than merely manufacturing products to other firms' specifications—or, worse yet, making counterfeit goods from stolen designs. While government officials acknowledge Taiwan's reputation as "counterfeiter's heaven," they adamantly assert that Hsinchu represents a step toward technological independence. "At this park, by God, everybody does their own thing," says Choh H. Li, director general of the complex. "There are no pirates here."

Government laboratories are throwing their resources into product innovation, long a weakness in Taiwan. The 12-year-old Electronics Research and Service Organization (ERSO), for example, employs some 800 engineers to design and fabricate integrated circuits. ERSO chips have found their way into products ranging from Timex watches to BMW automobiles. ERSO also makes circuits for several U.S. chip vendors, including Mosel (Sunnyvale, Cal.), Quasel (Sunnyvale), and Vitelic (San Jose, Cal.). Although ERSO stamps out 7–8 million ICs a month, selling the chips is not the main goal, explains Albert Huang, marketing manager for IC operations. Rather, he says, "we want to show our private industry that the IC can make money."

So far only one Taiwan company, United Microelectronics Corp. (UMC), has taken ERSO's demonstration to heart. One of the Hsinchu park's first tenants, UMC got its start by making integrated circuits with designs licensed from ERSO. UMC remains Taiwan's only commercial IC manufacturer, deriving 85% of its revenue from sales of proprietary products—principally memories for telephone dialers and melody chips for greeting cards and other musical novelties. UMC will bring out 50 new products in 1986, according to Robert H. C. Tsao, the company's founder and president. Like ERSO, UMC also sells its wafer fabrication services to foreign companies.

Although exports have been the mainstay of Taiwan's sizzling economy, the country now sees more than potential markets when it looks overseas. Some 50,000 nationals who sought education or jobs outside the country (mainly in the U.S.) have not returned. Thus, coaxing these expatriates back to apply their technical and managerial skills in their homeland is a central pillar of Taiwan's technology strategy. "We call them CEOs," says Li: "Chinese entrepreneurs from overseas."

The response has not been overwhelming. One reason is that technical

PHOTOGRAPHS BY DAVE BARTRUFF

While assembly lines turn out computers at the state-supported industrial park in Hsinchu (left), Taiwan still abounds with more traditional scenes. Above, Buddhists gather at Taipei's Lungshan temple.

professionals earn salaries many times higher in the U.S. than in Taiwan, where an electrical engineer brings in about $400 a month, a data-processing manager $1000 a month. Another is the government's decision not to offer large financial incentives to returning Chinese. "We don't want them to be in a different social class from their colleagues who have stayed in the country," explains Wang Chi-Wu, vice-chairman of the National Science Council. Such a distinction, says Wang, would mean "less mixing and hence less cross-fertilization of ideas."

Compounding the talent-pool problem is the country's dearth of educational facilities. There are far more willing applicants than there are slots in the country's institutes of higher learning. Only a third of graduating high school students can fit through the "narrow door" of the country's universities, says Wang. And added capacity will come slowly; even in a decade or two, the universities will have room for only 40% of high school graduates.

While Chinese engineers have hardly stampeded back to the island, there are some success stories. More than 70% of the companies in the Hsinchu park, for example, owe their start to the return of the native. A case in point is Microelectronics Technology, formed three years ago by engineers who left behind careers at large American electronics companies. The Hsinchu company, which makes microwave circuits for satellite communications, now ships 10,000 units a month, according to Patrick H. Wang, its Stanford-educated president. Asked why he returned after 17 years at Hewlett-Packard, Wang replies: "To come home." But he goes on to cite the low cost of engineers and other skilled labor compared with Silicon Valley's high-priced talent.

Another Hsinchu company, Tecom, was started by a 10-year veteran of Bell Labs, C-K Liu. Tecom makes an electronic telephone that it exports under its own name as well as other brands, such as Radio Shack. On the domestic front, the company is taking on such giants as AT&T, ITT, and NEC in its marketing of digital transmission equipment for telephone trunk lines.

Taiwan's promise and pitfalls spring

from some basic characteristics of the country's economy and culture. The Chinese put a high value on education, resulting in a well-schooled populace. Of particular benefit to foreigners is the ability of businesspeople at all levels to speak English fluently. (The older ones also speak Japanese, a vestige of the 50-year occupation that ended with World War II.) Perhaps the next most cherished virtue after education is thrift; the national savings rate of about 33% creates a large pool of available capital.

The Chinese are also entrepreneurs. In sharp contrast to conglomerate-dominated Japan and Korea, there are some 38,000 independent companies doing business in Taiwan. Almost all are small outfits owned and run by members of a single extended family. "You can predict the number of executives in a Chinese company by counting the founder's sons and sons-in-law," notes Arthur D. Little's Wasserman.

Unencumbered by bureaucracy, these nimble firms move quickly in engineering a new product and bringing it to market. It typically takes only three to six months for a Taiwan company to bring out a new computer terminal, a project known to take a year elsewhere. But some officials worry that the insularity of Taiwan's businesses may impede the country's march toward advanced technology. "It's unhealthy to keep a company in the family," says the National Science Council's Wang, because such inbreeding can stifle innovation.

Moreover, these small companies may lack sufficient resources to become serious competitors in world markets. Multitech, Taiwan's largest maker of microcomputers, has sales of only about $200 million. "There's no way a company that small can muster the capital to compete with, say, Samsung," declares Wasserman.

The government, though, is offering a helping hand. With enormous annual trade surpluses swelling Taiwan's foreign exchange reserve to $26 billion, the country can afford generous incentives. "The government has a lot of money," says Hsinchu park director Li—"more money than requests for it." To aid in establishing new companies, for example, the government will purchase up to 49% of any start-up that is targeting a strategic technology, such as microcomputers or telecommunications. The entrepreneurs can get a head start on equity, too, because the government grants them up to 25% ownership on the basis of their technological know-how alone. Thus the entrepreneur often need come up with only 26% in cash to control the company.

The favors don't end there. Companies are exempted from paying tariffs on equipment that is imported to manufacture any product appearing on the government's select list; such tariffs typically run 10–20%. Once production begins, the company can choose any five consecutive years during which its profits will not be taxed, and the maximum rate for high tech products is 22% (versus 35% in other industries). Other incentives include low-interest loans (two points below the prevailing rate) and a tax credit equal to one-fifth of a company's R&D expenditures. The latter aims to boost the portion of Taiwan's gross national product that goes to R&D from its present value of 0.9% to 2% over the next five years, according to Li.

Taiwan is not above using the blunt tool of protectionism to spur local technology development. Importation of videocassette recorders, for example, has been totally banned since 1983. The embargo has worked, after a fashion; several Taiwan companies have developed VCRs that are now marketed locally. But the units are not popular, according to Wan-An Yeh, vice-chairman

of the Council for Economic Planning and Development (CEPD). "People here lack confidence in the quality of a Taiwan-made product," he says, and instead buy machines smuggled from Japan. Yeh believes that such doubts will recede with time, as manufacturers gain experience with new products; he points out that native companies do a brisk business in locally made color televisions—a product that Taiwan factories have mass-produced for 20 years.

Taiwan's attempt to steer its economy onto a new course has been complicated by the Chinese tendency toward freethinking, in contrast to the Japanese consensus mentality. Uncertainty reigns, for example, concerning which technologies are officially sanctioned as strategic. The Industrial Development Bureau lists some 150 products, but every agency seems to have its own preferred subset. "There are at least five or six different lists floating around the government," admits CEPD's Yeh. "Even the staffs are confused."

CEPD's own list seems to summarize the government's priorities: information processing (including computers and telecommunications), precision machinery for factory automation, materials science (especially silicon and gallium arsenide for electronics production), biotechnology, energy, and optoelectronics. There is also one uniquely Chinese goal: control of liver ailments.

"Hepatitis is our national disease," explains the Science Council's Wang. The carrier rate among Chinese people is 10–12%, making it 100 times as prevalent as in the United States. The vaccine now administered to newborns is based on blood plasma, which entails the risk of contamination by blood-carried diseases such as AIDS. The government is therefore trying to genetically engineer a substitute. In addition to improving the population's health, the vaccine project is viewed as a way to enlist public support for technology. "It's a gimmick," says Wang, "a way to show that science can do something useful."

One sector that will need no convincing on that score is the military. About half the country's R&D spending goes toward defense, a reflection of Taiwan's almost four-decade fear of communist takeover. (The same worry has kept the island under martial law ever since 1949.) If this allocation bothers civilian leaders, they don't let on. "Give the military whatever they want; they're our life and death," says Wang.

Nevertheless, hefty defense budgets strain the country's technological resources. The situation is even more acute than it at first appears, because unlike the U.S., Taiwan has not developed a military-industrial complex. War-making hardware such as rockets and fighter planes are built by the government rather than contracted to private businesses. As a result, commercial spinoffs are rare.

Another problem in Taiwan's transformation is that even though its engineers are widely admired—"I give a company that I'm considering investing in a plus mark if their engineers come from Taiwan or Israel," says San Jose venture capitalist Robert Chappell—it has a reputation for poor quality control.

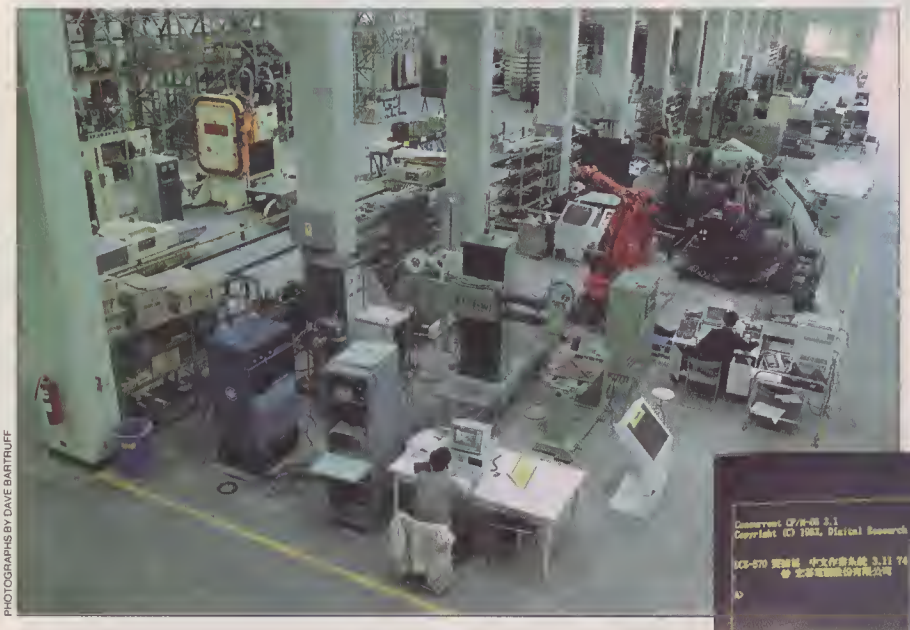
"Compared to Korea, Taiwan makes substandard products," asserts Gary Erickson, director of manufacturing at XO Industries (Mountain View, Cal.), which has contracted production of its electronic fluorescent-light ballasts to Taiwan factories. Erickson, who says he has worked with several Taiwan manufacturing operations while at XO and at his previous employer, ACS Communications (Scotts Valley, Cal.), claims that "the people in Taiwan are constantly substituting inferior plastics for the ones we specify."

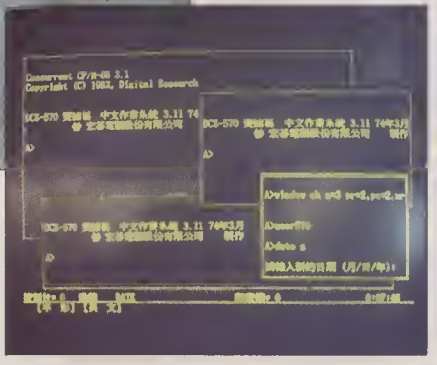
Foreign companies using Taiwan factories have faced another worry—that their design may be illegally copied. The distressing frequency of such piracy finally forced the government to get tough; since 1983, companies found to be manufacturing counterfeit goods have had their export licenses revoked. The crackdown seems to have worked: in 1982, according to U.S. Customs, more than half of all counterfeit products brought into this country were made in Taiwan; that figure declined to 20% the following year, and plummeted to a little over 2% by 1984.

Even if it manages to overcome the stigmas of piracy and poor workmanship, Taiwan clearly has a long way to go to achieve its intended technological transformation. Most of the country is still farming, making shoes, or serving as a short-order factory to foreign companies, and Hsinchu is so far its only technopolis.

In many respects, Taiwan is still very much an underdeveloped, third world nation. In Taipei, motorcycles swarm the streets, pouring noise and fumes into the muggy air, recalling TV images of wartime Saigon. Prostitution flourishes openly within a block of swank Western hotels, and foreign visitors are advised not to drink the water or eat the produce.

Of course, progress is relative. Ten years ago the city contained rice paddies and open sewers. As for what the coming decade will bring, Hsinchu park director Li gestures proudly out his window to the modern office and factory buildings sitting amid serene suburban lawns. "This," he asserts, "is the cradle of the future Taiwan." □





PHOTOGRAPHS BY DAVE BARTRUFF

Far left: National lab develops machines for factory automation, considered a strategic technology. Inset: Multitech's Chinese display spurs local computer use.

HONG KONG: The Chinese connection

Kowloon—In 1997 the bustling seaport of Hong Kong, along with Kowloon and the New Territories peninsula across the harbor, will revert from British to Chinese rule as a 99-year lease runs out.

Many had expected this hotbed of entrepreneurialism to cool down once British officials inked the 1984 agreement that would return it to the Chinese. But from an outcrop near Victoria Peak one could recently count 38 ships anchored in the harbor, feeding goods in and out of the second busiest containerport in the world. (Rotterdam is first; Hong Kong passed New York last year.) A new town of high-rises was being built on landfill below, and active construction could be seen over in the New Territories.

Meanwhile, industrial areas have sprung up in China just over the border from the New Territories and Macao, a nearby Portuguese colony that will also become Chinese territory in 1997. Labor-intensive manufacturing is being directed in these Chinese sectors mainly by skilled managers who cross the borders daily using photo identity cards similar to U.S. drivers' licenses. Chinese officials recognize that their nation lacks management talent in a generation suffering from the effects of Chairman Mao's Cultural Revolution (when university students and professionals were sent to the fields to work).

Hong Kong's forte in the recent past has been the ability to quickly jump into fad markets, from calculators and video games to Cabbage Patch dolls and Transformers (plastic toys that can be converted from cars or planes to robots by twisting pieces), and crank out products by the millions.

by Robert Haavind

But much of this activity was spawned by multinational corporations. Government support and nurturing of industries, so prevalent in Asian countries like South Korea, Taiwan, and Singapore, is totally absent in Hong Kong. "If a company gets in trouble here, it fails. We don't help anyone," states Andrew Simpson of the Hong Kong Trade Development Council. One result of the government's laissez-faire stance is a tax rate low enough to attract many companies: 18.5% maximum for businesses and 16.5% for individuals.

Even though the Hong Kong government does not get involved with individual industries, a study of how it might help industry in broader ways was launched after a recent business downturn, explains A. G. Eason, deputy director of industry for the Hong Kong government's Industry Department. One way the government will help, according to Alice Lai, assistant director for industry support, will be to do forecasts of markets and industries in target countries. An example might be a study of the changing tastes in appliances in the U.S. and Europe. Courses of study at local universities might also be tuned to projections of future business directions for Hong Kong.

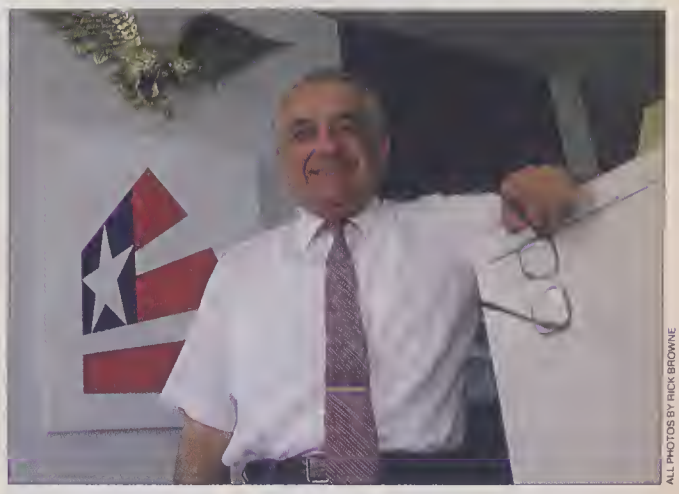
Government is also urging industry to move toward advanced automation and precision manufacturing. For example, a new Hong Kong Standards and Calibration Laboratory is being set up and accredited by the British standards organization, and manufacturers will be encouraged to put in calibration facilities of their own as well.

Computer-aided design and computer-aided manufacturing are areas that many feel will become important to Hong Kong. With computer networks and powerful design software, integrated circuits and mechanical parts could be designed anywhere in the world, according to Victor Fung, managing director of Li & Fung Ltd., an investment and trading firm. In particular, he notes, more skilled work might be done in Hong Kong, with less advanced design being assigned to China. Already, considerable software work is being contracted by China, where wages are five times less than Hong Kong's, according to Donald Taylor, technical director of the Productivity Council, while systems analysis is being done in Hong Kong.

The colony's businesspeople believe that China will discover great synergism in working with the skilled, entrepreneurial people of Hong Kong. What's more, their long-time ties to China give them an exceptional understanding of the Chinese system. They see their region as providing a vital link between the Western world and the awakening giant at their doorstep.

For example, the Chinese plants springing up at the borders with Hong Kong's New Territories and nearby Macao may be harbingers of the future. Techno-Ventures (Hong Kong) Ltd. is a new investment firm that plans to extend the "twin-factory" concept as China emerges as a major force in global trade. According to Fung, who is chairman of the investment group, a prototype factory can be built in Hong Kong. Then, once the plant is operating efficiently, a larger version can be set up in China. Using Hong Kong as a staging area will allow a firm that wishes to get into the Chinese market to build an infrastructure first, explains Fung, with the engineering talent, communications, banking facilities, and other elements needed to support it within

Hong Kong continues to attract investment, such as the new Techno-Ventures fund, headed by Victor Fung (left), which will finance prototype factories in Hong Kong to serve as models for sister plants in China. Meanwhile, automation is moving into industries such as injection-molded plastics (Design Futures Toy Co. assembly line, below left) and garment making (Fang Brothers automated knitting machines, below).



ALL PHOTOS BY RICK BROWNE

Services, often based on technology, will be Hong Kong's greatest future strength, says Donald Taylor (left), of the Productivity Council. John Goudey (above), head of the American Chamber of Commerce, says Americans now outnumber British in Hong Kong (15,000 to 14,900), mainly because of emerging China trade.

China. Techno-Ventures has already raised over $22 million, and plans about 30 projects in the next three years, ranging from about $500,000 to $3 million in size. According to Fung, the companies will tend to be in medium rather than high technology areas. The Chinese have responded very favorably to the idea, he says, and may set up a fund of their own to do similar projects.

China has rules that must be considered by companies going into such projects, however. Over a period of 15 years (25 in some cases), a company will be permitted to keep 75% of its profits while giving the rest to China. Afterward, the entire operation must be turned over to the government. The Chinese indicate that they may not buy goods from vendors unless they build plants in China under these terms.

Fung points out that even these tough conditions won't discourage projects with a high enough rate of return. "The technology of the plant will probably be obsolete in 15 years anyway," he suggests, and the manufacturer may be able to build a new plant financed by profits from the first one.

Hong Kong has not had a venture capital industry in the past, according to Fung. Most businesses have been family-financed, and expanded through local banking contacts. He believes that the potential for prototype plants in Hong Kong now make it an attractive place for venture capital. But still, he feels, while Hong Kong will provide front-end services (marketing, product design, and tooling), as well as back-end and tertiary services (banking, shipping, testing, packaging, and customer service), it will lose the labor-intensive manufacturing sector to China.

Thus, even though Hong Kong hasn't stopped bustling, there will be changes in direction. Technology has a bright future here, but more in providing services than in manufacturing, predicts Taylor of the Productivity Council.

As automation is mastered by Japan, the U.S., and European nations, Taylor sees much manufacturing returning to those nations to be closer to their marketplaces, thereby allowing smaller-scale production, more customization, and faster turnaround. He sees Hong Kong concentrating on being a trading center, with high tech buildings and advanced systems for communications, financial transactions, and other services. He believes it will serve as a gateway to southern and central China, with activity centered in Canton and Shanghai. In contrast, Japan is more active in Northern China, where Beijing is located.

Even though Hong Kong's future may not be as a manufacturing center, the strengths it does have should prove vital as links to China are reinforced. These strengths lie in three industry sectors: injection-molded plastics, garments, and electronic assembly. More advanced manufacturing technology is beginning to move into each of these areas, a trend that will make collaborative efforts even more attractive to the Chinese.

The lack of physical space has made Hong Kong the home of the vertical factory, and many cramped facilities still use rudimentary labor-intensive production methods. But Hong Kong labor rates have been rising. They are now more than three times those in Malaysia, according to John Goudey, executive director of the American Chamber of Commerce. Thus manufacturers are turning to automation to boost productivity.

One way Hong Kong companies are upgrading technology is through partnerships with overseas manufacturers. A good example is Nyprochen, set up jointly by Chen Hsong in Hong Kong and Nypro, a Clinton, Mass., plastics manufacturer. In its New Territories plant, which turns out about 300,000 injection-molded plastic pieces a day, an IBM PC/AT monitors operations, and all machines are robotized for loading. Dyed material is sent from drying silos to machines through overhead pneumatic tubes with electronic switches that guide materials to the proper workstations. According to Ngai Chang Yu, a manufacturing manager, Nyprochen is one of the first plants in Hong Kong to use a torpedolike device that feeds heated plastic into a mold, thereby eliminating the waste material that must normally be trimmed off plastic parts.

There are over 3000 injection-molding shops in Hong Kong—the densest concentration in the world, according to Stephen Kroll, director of Asian

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Commodore's well-organized printed circuit board assembly line (above) has the "most advanced testing facility" in Asia, aside from Japan, according to general manager John Mallaris (left).

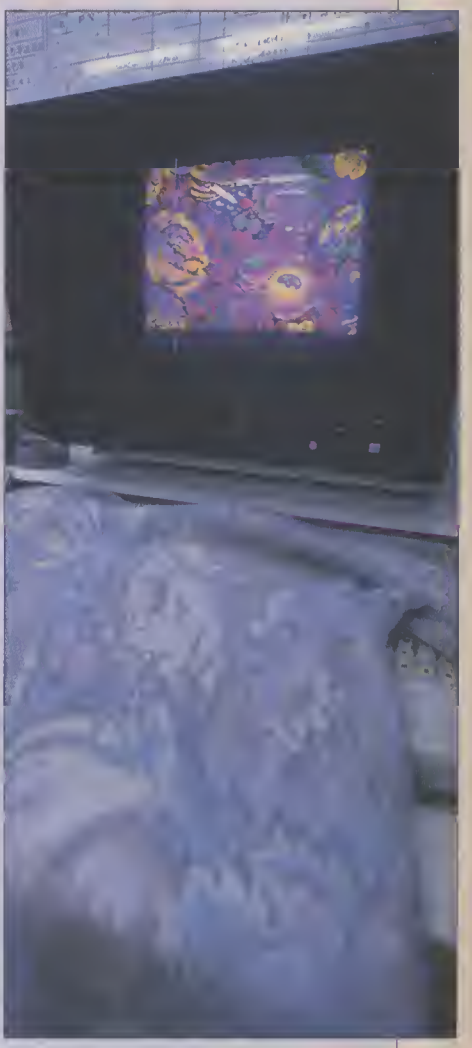
How sweater makers unraveled U.S. trade barriers

For several years, panels for women's sweaters were knitted in China and then stitched together in Hong Kong. The market grew rapidly as women in the United States bought fewer blouses and more sweaters—cotton for spring and fall, wool for winter. The U.S. garment industry, stung by competition from low-cost imports, initiated legislation to designate China the country of origin rather than Hong Kong, thus boosting import duties because China was not a favored trading nation. (Country of origin is defined by where the most substantial transformation takes place; this was shifted from stitching panels together, the Hong Kong operation, to knitting the panels, which was done in China at very low labor rates.)

The result, explains Kenneth Fang of Fang Brothers Knitting, was that Hong Kong producers bought about $400 million in automation equipment from Japan in 1985 so they could do the whole job themselves. Substantial business was thus taken away from China, while Japanese makers of computer-controlled knitting machines, some of which had been facing financial troubles, hit a bonanza.

Advanced technology boosts efficiency through all phases of sweater making. Designers do a rough color drawing that is turned into stitch-by-stitch computer instructions by using a large, colorful display on a special-purpose Shima Tronics computer (Fang Brothers developed its own software). Templates help an operator to manipulate a large array of function keys while inputting stitching instructions. Knitting machines run by the resulting code operate 24 hours a day, seven days a week. One operator can tend six to eight machines, each of them producing 5–10 dozen panels a day.

Hong Kong still sells about the same volume of garments to the U.S., according to Fang, but lower labor costs in places like Taiwan have forced a move upscale. So vendors' profits are increasing as they use their highly automated mills to make higher-quality (and higher-priced) garments.



Manufacturing Services, the firm that set up the Nyprochen partnership.

Automation is proceeding even more rapidly in some parts of the garment industry, spurred by import restrictions imposed by the United States (see "How sweater makers unraveled U.S. trade barriers").

Hong Kong vendors used to compete solely on price, but now the competition is more on quality and fast turnaround, says Kenneth Fang, director of Fang Brothers Knitting Ltd. By moving up the quality scale, Hong Kong is increasing dollar volume about 20% a year while making the same number of pieces. "Hong Kong is losing the low-end market; chains like K-Mart, J. C. Penney, and Woolworths now buy from China and Taiwan," says Fang. "Meanwhile, we make designer labels and sell to Bloomingdales and Saks."

In the old days the typical Hong Kong garment factory was a large building with a huge production line. About five years ago there was a major shift to smaller facilities. Each of the six production floors in Fang's nine-story knitting mill operates more or less independently, three doing computer-controlled knitting and three doing the looping that stitches a set of panels into a finished sweater. This allows much greater flexibility, making short runs convenient. "We can change a setup in the morning and have finished goods at night," boasts Fang.

Electronic assembly, which along with plastics and garments makes up about 80% of Hong Kong's exports (most of the rest consists of hardware items), is also being upgraded. At Commodore's 11-story assembly plant for its model 64 and 128 computers, general manager John Malliris recently installed what he claims is "the most advanced electronic testing facility in Asia." (He explains that his use of "Asia" doesn't include Japan.)

Just as in garments, Hong Kong electronics firms stress fast response to market demand, which is especially critical for consumer electronic products like Commodore's computers. A good example is the use of jumper wires to change the language used by a computer's software by shifting the access point on a read-only memory. "Otherwise it would take three days to make a new board for another country," says Malliris.

The Commodore plant has a fully automatic line that plates leads onto plastic integrated circuit packages at rates of up to a million chips a day. "It's the only one in Hong Kong," asserts Malliris, who designed it himself.

Before mid-'85, the plant was run "the Chinese way," he says. Now workstations are neatly organized, parts and materials flow to where they're needed, and workers don't have to move around to perform their jobs.

Still, Commodore's most advanced computer, the Amiga, is being produced in Japan, which Hong Kong lags considerably in manufacturing sophistication. As the Chinese work cooperatively with the Hong Kong government to smooth the transition in 1997, however, manufacturers seem willing to continue investing in upgrading production facilities. This brightens the future for both Hong Kong and China. □

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Special Report

FOUR TIGERS OF THE ORIENT

SINGAPORE: Can the littlest Tiger restore its roar?

Singapore—For more than 20 years, Singapore has been honing its reputation as Southeast Asia's "can do" country. Thanks to a well-educated and well-paid workforce, a superb Western-style infrastructure, and a no-nonsense government renowned for its integrity, this tiny island republic has long been a top manufacturing and service center for multinationals such as Texas Instruments, Bell Helicopter, and Hewlett-Packard. Until 1984, in fact, a bad year in Singapore was one in which the republic scored a mere 5% growth rate; annual rates of 8, 10, and even 15% were more typical.

But those were the days when shipbuilding and oil refining accounted for about half of the nation's economy. As demand for oil, petrochemicals, and supertankers skidded in 1984–85, so did the Singaporean economy. Adding to the injury was the slowdown in the U.S. computer industry and the corresponding nosedive in markets for peripherals and other electronic products made in Singapore for multinationals. As a result—and for the first time in recent memory—the national economic growth rate fell slightly below zero last year, to −1.8%. Although some Asia watchers predict a 1–1.5% growth rate this year, Singapore officials think even that figure may be too optimistic. Meanwhile, the 1986 figures for South Korea and Hong Kong are predicted by their governments to be 7 and 4%.

Like many other heavy-industry regions, Singapore is out to reverse its fortunes between now and the early 1990s, through both economic policy changes and long-range industrial goals. Countering the republic's image as a relatively pricey place to do business, for example, the government earlier this year persuaded workers (who are among the highest paid in the region) and trade unions to adopt an effective wage freeze during the next two years. Labor costs are also being trimmed by a reduction in employers' contributions to the Central Provident Fund (in essence, a mandatory worker-retirement account) from 25% of employees' salaries to 10%.

On a longer-term basis, Singapore

R. IAN LLOYD/BLACK STAR

As managing director of Diagnostic Biotechnology, Lim Jiu Kok chose Singapore as a corporate site largely because of its modern facilities and supportive government. The company, which develops new medical diagnostic techniques, is one of more than 20 residents of the government-sponsored Science Park—a focal point for R&D in biology, computer graphics, and other technology areas.

by H. Garrett DeYoung

has set out to attract new technology-based ventures. And while the nation still depends heavily on manufacturing and assembly processes, the aggressively pro-business government is sparing no effort to put high tech color in the nation's economic cheeks. One important step was taken two years ago, when R&D funding was boosted to 0.6% of the GNP—still far from the United States' 3% or Japan's 2.5%, but double the 1981 rate. Disciplines now enjoying top priority include microelectronics, life sciences, robotics, artificial intelligence, and communications.

"Frankly, we're anxious to attract new investment of any kind," says Vincent F. S. Yip, executive director of the government-backed Singapore Science Council, "whether it's in manufacturing, distribution, finance—whatever. But within the next five or ten years, the real heart of our economy will be advanced technology developed right here in Singapore."

The government is tapping both academe and business in order to achieve its technological goals. One approach is to polish up the R&D capabilities of the nation's small but highly regarded academic community—specifically at the Nanyang Technological Institute and the state-run National University of Singapore (NUS); major NUS programs are now under way in genetic engineering, diagnostics, and computer sciences.

A second and more aggressive approach is to make Singapore virtually irresistible as a place from which to do business. And with a population of only about 2.6 million, the nation recognizes the need to attract entrepreneurs from all over the world. Adding to the allure of a modern and efficient infrastructure and a prized location on the doorstep of the Pacific marketplace, the government provides some powerful financial incentives:

- "Pioneer-industry" status, in which R&D-oriented companies can enjoy several years of tax-free profits.
- The $30 million Research and Development Assistance Scheme, administered by the Singapore Science Council, which provides financial aid of up to 100% for companies engaged in programs of national importance.
- The Product Development Assistance Scheme, by which the government pays up to half the costs of commercializing a product or process.
- Initiatives in New Technologies, a program aimed at relieving the costs of personnel training and start-up.

The country has also recently set up a $50 million venture-capital fund, Venture Investment/Singapore, for supporting new projects in robotics, biotechnology, and computer sciences.

If the government has its way, much of the new technology will wind up in the three-year-old Science Park, a few miles from NUS. Managed by the Science Council (part of the Ministry of Trade and Industry), the cluster of modern buildings is clearly intended to be a highly visible technological focal point; prospective residents are lured to the site by attractive rental rates, research grants, consulting services, and short start-up times.

Science Park is now home to more than 20 new and established companies, all geared to developing and marketing advanced technologies. Examples include Mentor Graphics Singapore, a leading designer and producer of computer-aided engineering systems and workstations; Det Norske Veritas, a materials-testing and analysis laboratory with head offices in Norway; and Radan Systems, a subsidiary of Britain's Radan Computational Ltd., which also specializes in CAD/CAM development and marketing.

"This is a very small country, so we're especially interested in attracting technologies that don't require a lot of room," says Yip. "You can work on artificial intelligence in an average-size office, but you couldn't do that with ceramics or advanced engines." Another criterion for new Singapore technology, he says, is its commercial applicability to the country and its neighbors.

One technology area that meets this requirement is agriculture. Even though Singapore itself is not among the major markets for new agricultural technology—it covers only 225 square miles, roughly the size of Chicago—many of its neighbors are. Thus several Singapore-based companies are now designing methods for creating new crop species and for stepping up agricultural productivity. In Science Park, for example, researchers at Plantek—a three-year-old joint venture between Native Plants Inc. (NPI) of Salt Lake City and Tata, an Indian crop-genetics company—are applying innovative plant-genetics techniques to regional crops such as oil palm, coffee and tea, and pineapple.

"Agriculture accounts for up to 65% of the economy in some Southeast Asian countries," says Brian Gambrill, Plantek's managing director. "We now have the marketing rights to all of NPI's technology throughout the region."

Like its U.S. counterparts, Plantek is staking its future on several recently developed technologies. In one such method, protoplast fusion, individual cells from different plant species are fused into a single new cell; the new organism will presumably carry genes from both its parents, thus imparting interesting and potentially useful properties to future generations. In another technique, called somaclonal variation, cells grown in culture are subjected to a variety of hormonal manipulations in the hopes of generating new properties, such as resistance to disease and drought. The company is now marketing about 40 new plant species throughout Southeast Asia.

Plantek is one of several Singapore companies that enjoy pioneer-industry status, which in this case grants immunity from taxes for seven years; the company also received a $500,000 R&D assistance grant, which will be shared with NUS. "The government wanted us here very badly," says Gambrill.

Elsewhere in Science Park, five-year-old Everbloom International has patented a method for growing the exotic Chinese black mushroom (called shiitake by Japanese producers, who own about 95% of the international market) in less than a tenth the time required with the traditional method of growing the fungi in oak logs. CEO Tan Kok Kheng estimates the annual worldwide shiitake market at about $1 billion.

Like Plantek, Everbloom enjoys vigorous government support, including a $300,000 research grant that may help it expand into health-related technology in the near future. "Many mushrooms have a lot of interesting properties," says Tan, citing the shiitake's apparent ability to kill cancer cells (perhaps by triggering interferon production in the body) and to control cholesterol. Company researchers are now working to identify and isolate the active ingredients.

Another Science Park tenant, Diagnostic Biotechnology, is developing several medical diagnostic methods aimed at T-cell leukemia, AIDS, nasopharyngeal cancer, and hepatitis B (a major health problem in Asia). Clinical tests for many of the company's products are now being planned for the region ("they're too expensive in the U.S.," complains managing director Lim Jiu Kok), with marketing aimed at Europe, Australia, and perhaps Japan.

Although the company was wooed by Taiwan during its formative years, says Lim, "we were really impressed with Singapore; it has a very supportive government, a modern communications network, and a complete lack of language barriers." He adds, however, that the company has occasionally struggled to find researchers experienced in diagnostic principles and in tissue culture (the art/science in which living cells are grown to large volumes in the laboratory).

NUS will also be influential in Singaporean biotechnology with its $18 million Institute of Molecular and Cellular

Biology, scheduled for completion early next year. Although the institute will be geared toward research, says NUS liaison officer Peter Lim, "an important task will be to provide personnel and advice to local biotechnology companies." Discoveries made at the institute could also be licensed to companies around the world.

Computer science has also taken a lead position in Singapore's future. The movement was sparked and is being led by the government's National Computer Board, which serves as the official coordinating agency for computerizing Singaporean commerce and industry and for promoting the nation's emerging software capabilities. Early research is now being conducted in CAD/CAM systems, computer graphics, and local-area networks.

The unofficial prime mover of the technology is NUS's Institute of Systems Science (ISS). Created largely with consulting services provided by IBM over a four-year period, ISS is taking a decidedly industrial tack. "Singapore's major strength in electronics has always been in manufacturing," says ISS director Juzar Motiwalla, alluding to the production of Texas Instruments' IC test equipment and Motorola's PC boards. "We aim to build on that strength by developing new and more innovative approaches, such as software and information systems."

To accomplish that, ISS is divided into two major segments: education and research. The former is geared mainly to promoting computer awareness and utilization within Singaporean industry by offering courses for top corporate managers and executives, especially in small business.

The research division, meanwhile, is now conducting programs in computerized public information, telecommunications, office systems, and software based on Chinese characters—all applications that remain relatively undeveloped in Singapore (except for telecommunications, which Motiwalla calls "the second-best developed system in Asia, after Japan").

To be sure, the island is not without its problems. With its small population, Singapore's fortunes will always be linked to the economies of Europe, the U.S. (which buys about a fifth of its exports), and Japan. And while the nation's compactness means easy maneuverability—both on the roads and through the bureaucracy—it also imposes constraints on the nation's ambitious timetable. "How do you squeeze all the technology you need from just 2½ million people?" asks Yip.

Observers also have mixed reviews of the government's strong (some say heavy-handed) central-planning policies: although such policies are credited with having achieved Singapore's tidy, fresh-scrubbed appearance and almost total lack of racial and political strife, they also come across from time to time as paternalistic and innovation-stifling.

But such quibbles pale beside the enthusiasm with which the republic is stepping off into the next decade—an enthusiasm that sees even the island's tininess as an advantage rather than an obstacle. "We can't delude ourselves into thinking that we can accomplish everything we set out to do," says Motiwalla. "At the same time, because we're a small and adaptable nation, we've shown that we can move very quickly into new areas." □

DAVE BARTRUFF

Its modern skyline belies Singapore's troubled economy, which is tied to shipbuilding, oil refining, and foreign technology. But the republic now aims to develop its own expertise in such fields as CAD/CAM and telecommunications. For example, says the National University's Juzar Motiwalla (right), "we're searching for more innovative approaches to creating our own software and information systems."

For further information see **RESOURCES**, *p. 69.*

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Innovations like programmable ICs and device libraries are helping nonexperts design custom chips

by Jeffrey Bairstow

Within the last three years, application-specific integrated circuits (ASICs) have begun forcing radical changes in the way ICs are designed and manufactured, and have even started changing the way chip suppliers do business with their customers. ASICs—integrated circuits whose functions are specified by the user—are often produced by a specialist maker, as opposed to general-purpose ICs, such as memory chips and microprocessors, made by the large merchant semiconductor manufacturers. An ASIC may be as complex as a microprocessor or as simple as a single-chip controller for a coffee maker.

Today, the system designer has available a vast array of ASIC devices, from simple logic elements that may be programmed on the engineer's desktop to predesigned libraries of complex circuits such as microprocessors and modems that can be assembled automatically on the same chip. Some manufacturers offer a wide variety of ASIC technologies, so an engineer may design and prototype a chip with the simplest and least expensive circuits and then move up to more sophisticated IC techniques for manufacture in volume. And it may soon be possible to check out and prototype a design within 24 hours. In addition, the software tools needed to design ASICs are now widely available for relatively inexpensive workstations and personal computers (HIGH TECHNOLOGY, June 1985, p. 18). Consequently, the ASIC business is booming.

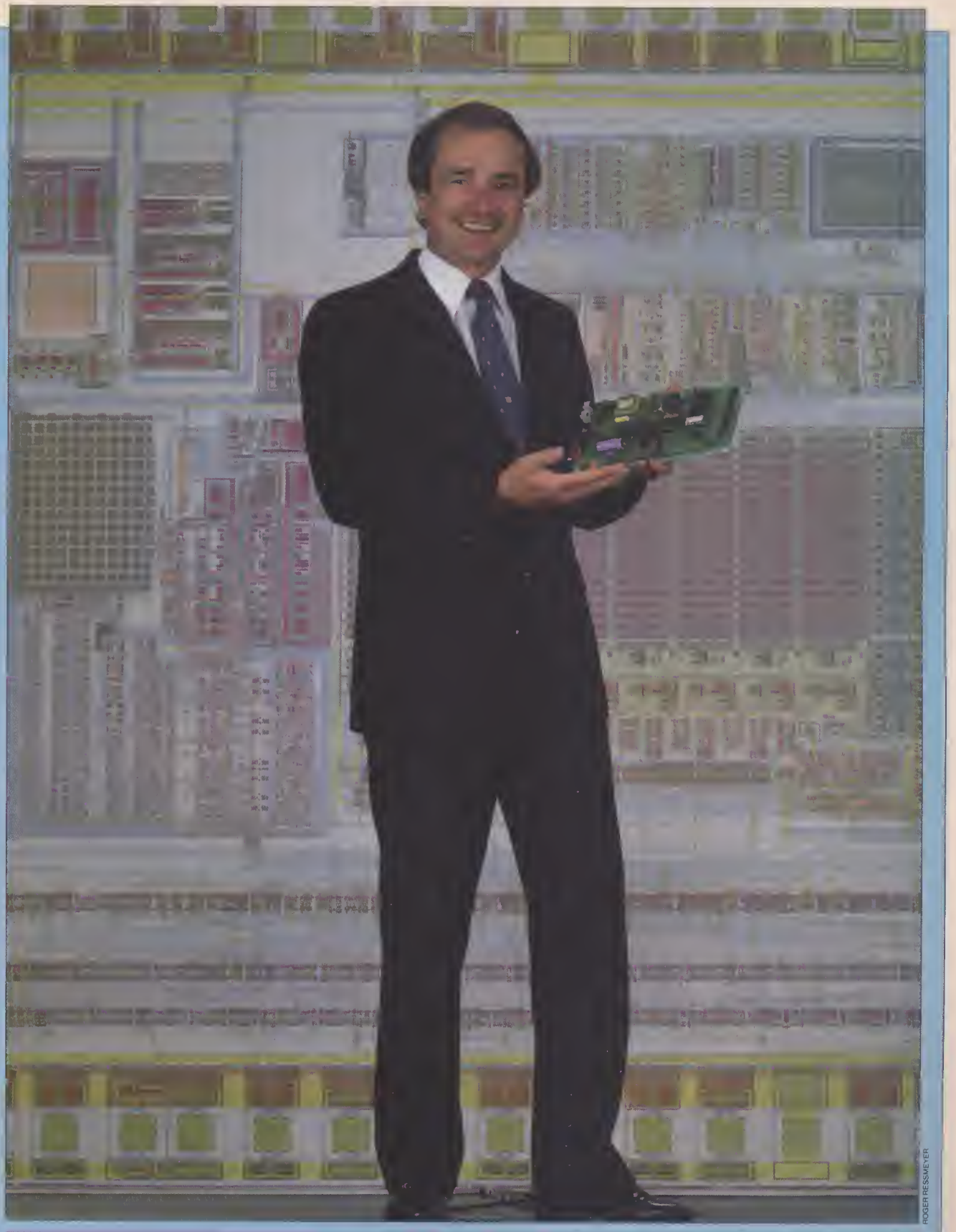
ASIC revenues are expected to reach $5.8 billion this year and to zoom to $13.1 billion by the end of the decade, according to Andrew Prophet, a senior industry analyst with Dataquest (San Jose, Cal.). By contrast, the worldwide semiconductor business as a whole has recently been declining at a 20% annual rate.

The advent of ASICs is bringing IC design capabilities to a broad new constituency. "Last year, semiconductor manufacturers generated fewer than 10,000 new IC designs," says Andrew Rappaport, president of The Technology Research Group (Boston). In essence, about 4000 IC designers, employed mostly by the merchant semiconductor companies, produced an average of one design each, while some of the more than 200,000 electronic system designers turned out about another 5000. But while few system designers currently have the IC experience or familiarity with the available automated tools to produce their own ASIC designs, that situation is changing rapidly. In just four years, claims Rappaport, system designers alone will create almost 100,000 new designs per year.

Because the traditional methods of producing ICs simply cannot cope with such a flow, ASIC designers are often turning to "silicon foundries," companies that do little design work but exist to turn out chips devised largely by their customers. Meanwhile, merchant semiconductor makers, faced with the prospect of losing 30% or more of the IC market to entrepreneurial foundries, are not standing idly by; instead they are scrambling to set up their own ASIC design centers, which furnish customers with proprietary computer-based tools to design their own ASICs for manufacture by the IC vendor. Using a display terminal or workstation, the customer can design and check the logic of the circuits, as well as simulate the function and timing of the design.

The growth of the ASIC business is driven by two forces, says Peter Richmond, marketing manager for General Electric's Custom IC Department (Research Triangle Park, N.C.)—"the rapid development of silicon-gate CMOS [complementary metal-oxide silicon] technology and the increasing advancement of CAE [computer-aided engineering] tools for IC design." In the first case, he says, the turning point came about five years ago with the development of 5-micron CMOS circuits, which permitted more than 1000 logic gates on a single chip. ("Five-micron" refers to the average length of a gate, the basic logic element.) Today, notes Richmond, 2-micron technology is cramming more than 10,000 usable gates onto a chip. Several manufacturers will shortly introduce 1.5-micron gate arrays, which will effectively double the possible number of gates. What's more, some memory makers in the U.S. and Japan are already preparing for submicron technology, although that level of integration is not yet required for ASICs.

While semiconductor manufacturing technology is always a step or two ahead of the potential users of ICs, claims Richmond, "CAE tools tend to lag the users' needs. We're just beginning to see personal computer–based CAE tools that can comfortably handle the design and simulation of circuits with up to 2000 gates." The trend in ASIC design is away from expensive, dedicated workstations, such as those made by Daisy Systems (Sunnyvale, Cal.) and Valid Logic (Mountain View, Cal.), in favor of PC-based systems, such as those offered by FutureNet (Chatsworth, Cal.) and Telesis Systems



ROGER RESSMEYER

"With design tools based on artificial intelligence, we'll bring the best IC designers' know-how to the system engineer."
DON MACLENNAN, DIRECTOR OF MARKETING, SIERRA SEMICONDUCTOR

(Chelmsford, Mass.), and general-purpose engineering workstations.

More sophisticated engineering workstations, such as those made by Apollo Computer (Chelmsford, Mass.) and Silicon Graphics (Mountain View, Cal.), can handle around 5000 gates easily, says Richmond, whereas 10,000-gate circuits and larger still require the capability of a mainframe computer, typically a Digital Equipment Corp. VAX system. But as PCs add more memory and increase their processing speeds, he says, the size of the IC designs they can handle will increase dramatically.

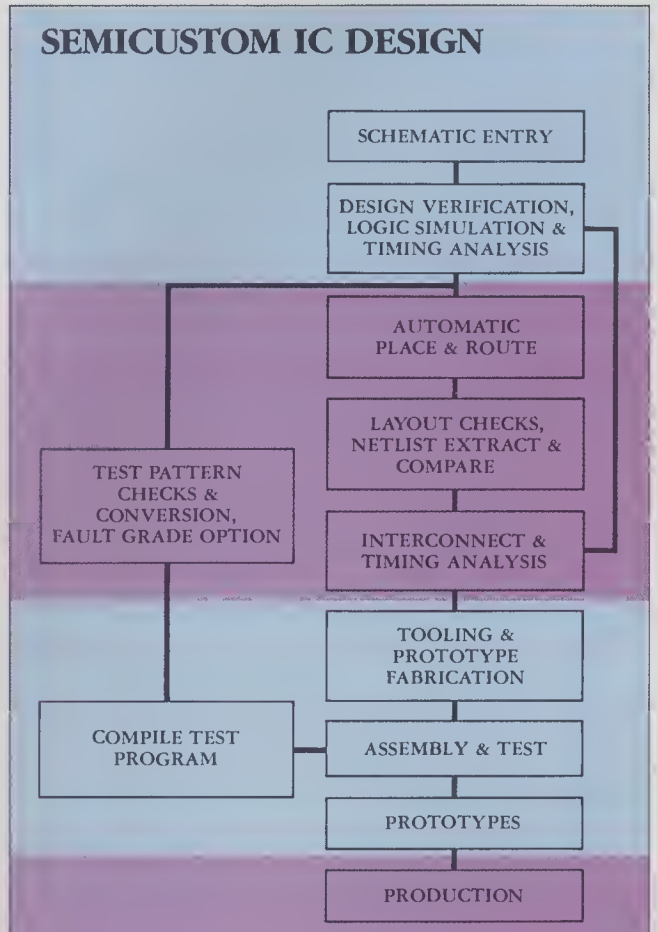
There are three basic ways of designing integrated circuits, all of them requiring automated tools for entering and simulating the design: gate array, standard cell, and custom. All three methods may be used to design ASICs, depending on the complexity of the circuit and the volume of chips to be manufactured.

The simplest technique, and probably the most frequently used, is the gate array. As the name implies, a gate array is a standard array of logic elements, or gates, diffused into a silicon chip. The connection of the gates is determined by the system designer and accomplished with one or sometimes two layers of metal interconnections deposited on top of the silicon. A typical gate array will contain anywhere from a few hundred to a few thousand gates. However, gate array manufacturers are constantly increasing the density of gates on a chip. Arrays of more than 100,000 gates are now possible, says Rick Rasmussen, product manager for LSI Logic (Milpitas, Cal.), the leading U.S. manufacturer of gate arrays. Not all the gates on a chip are used: the interconnections would be too complex. Several major Japanese semiconductor makers, notably Fujitsu and Toshiba, have also been successful in making large gate arrays.

The standard cell approach is based on predefined integrated circuit designs, such as buffers, gates, flip-flops, decoders, and multiplexers, each forming a standard building block or cell. From a library of cells, provided by the IC maker, the designer builds a circuit with the desired functions. Design automation tools are used to lay out the standard cells on a chip and route all the interconnections. Since the range of functions available in a standard cell library is extensive, such designs are often more complex than gate array designs. Standard cells also achieve higher circuit density and so make more efficient use of the silicon real estate. Production, however, is more complex—comparable to that of general-purpose ICs.

The leading standard cell vendor is probably NCR Microelectronics (Fort Collins, Colo.), which has a codevelopment alliance with Motorola (Phoenix, Ariz.) that allows customers to switch freely between the two companies' gate array and standard cell options. Other leading standard cell vendors are VLSI Technology (San Jose, Cal.), an ASIC vendor with a highly regarded tool library; and Zymos (Sunnyvale, Cal.), a company recently purchased by the Korean conglomerate Daewoo.

Chips designed through gate array and standard cell techniques are often referred to as semicustom integrated circuits, since they use predefined elements. Thanks to design automation tools developed by semiconductor makers, silicon foundries, and specialized software houses, neither technique requires much IC design experience. In contrast, full custom circuits are designed from scratch by experienced IC designers to achieve the maximum packing of transistors and other circuit elements on the chip. Because full-custom design and layout is more expensive and time-consuming than semicustom methods, it is used only when extremely high performance is warranted—as in the case of a microprocessor—or when production volumes are expected to be large enough to justify the additional costs. The major companies in the full-custom field are the leading merchant semiconductor makers, notably Intel and National Semiconductor (both in Santa Clara, Cal.), Texas Instruments (Dallas), and such Japanese makers as Fujitsu and Toshiba.



Development of an application-specific IC has four major phases: design (usually on a workstation), layout (often on a larger computer), prototyping (at the vendor's production facility), and production.

For semicustom circuits, whether gate array or standard cell, the design, testing, and manufacturing process is largely the same (see diagram). There are four phases: a design phase, taking two to ten weeks, either at a vendor's design center or on the system engineer's own workstation; a layout phase, taking one to four weeks, usually on the semiconductor vendor's mainframe computer; a prototyping phase, taking four to eight weeks, at the vendor's production facility; and finally a production phase, taking perhaps 12 to 14 weeks to reach full volume.

In designing a circuit, a system designer using an engineering workstation or a PC-based CAE system begins by selecting the necessary logic elements from the standard cell library offered by the semiconductor vendor, a process called schematic entry. The system designer then uses a logic simulator on the workstation or PC to check that the logic will function correctly. A second simulation program checks for timing problems.

When the designer is satisfied, a network listing (netlist) is generated so that either the vendor's mainframe CAD system or the designer's workstation can automatically place the standard cells on a chip layout and determine the routing of the interconnections. The system checks to ensure that none of the design rules for

that particular semiconductor technology have been violated, and performs a timing analysis using the actual timing delays caused by the interconnections produced by the layout program.

Once the layout is verified, the semiconductor maker produces the photolithographic masks needed to etch the silicon, and prototype circuits are built for testing by the system designer. If the prototypes are successful, the vendor can then make the circuit in volume. The Motorola-NCR alliance permits system designers to develop and prototype a design as a gate array and then convert the logic to a standard cell version with the help of computer-aided design tools. Gate arrays can be prototyped faster and at lower cost, while standard cell designs can often be manufactured less expensively at larger production volumes.

Prototyping time can be cut even further with a laser-programmable gate array technique developed by Laserpath Corp. (Sunnyvale, Cal.). Laserpath programs arrays by cutting away unwanted connections on a premetallized array, a process that takes about three hours for a 1500-gate chip. "Ultimately," says company president Michael Watts, "we expect to achieve one-day turnaround" after receiving the chip layout. The company charges $13,500 for five 1500-gate prototype chips, about half the cost of conventional gate arrays.

The laser-cutting technique is available only through an ASIC vendor. But an alternative, the programmable logic device (PLD), can be modified directly by the system designer. One form of PLD is the programmable array logic (PAL)—supplied by Monolithic Memories (Santa Clara, Cal.)—which contains up to 2000 logic gates. At each intersecting point in the logic array is an electrically programmable connection; depending on the logic design, some of these connections will be opened during programming.

Another form of PLD is an erasable programmable read-only memory (EPROM) with a gate array architecture. Logic design with an EPROM is similar to other semicustom methods. The designer begins with schematic entry and proceeds through verification and simulation to produce a netlist. Special software provided by the PLD maker converts the netlist into instructions for electrically altering the state of the connections. If the prototype PLD is not satisfactory, the design can be reworked and the EPROM erased by a short exposure to ultraviolet light. The PLD is then ready to be reprogrammed.

At densities of less than 2000 gates, a PLD can be used as a relatively inexpensive gate array prototype. "It's safe to assume we haven't seen the limits of PLD density," notes Rappaport, and performance and capacity are in fact increasing. Several merchant semiconductor vendors offer EPROM devices, but the most active suppliers in this area are relative newcomers such as Altera (Santa Clara, Cal.), Cypress

Custom chips outpace conventional circuits

The market for application-specific integrated circuits (ASICs) is flourishing, even in the midst of slow growth for semiconductors generally. According to Dataquest (San Jose, Cal.), ASICs will expand by 25–30% this year—a growth rate almost three times that of the total IC business—to constitute a worldwide market of $5.8 billion. "ASICs could account for up to half of the total IC market within 10 years," says Wilfred J. Corrigan, president of LSI Logic (Milpitas, Cal.). "By 1990, ASICs will represent a $12–15 billion market."

The ASIC market is composed of four segments. Over half of it consists of fully customized circuits—extremely compact and capable devices whose high development costs make them most suitable for use in high-volume goods such as watches, calculators, and other consumer products. The market for such ICs, however, will remain essentially flat into the next decade as design-automation tools, such as computer-aided engineering (CAE) workstations and silicon compilers, grow in power and sophistication.

Thanks to such tools, gate arrays and standard cells—less complex ASICs that make use of some predefined elements—will take over a larger share of the market. The gate array market will rise from $2 billion in 1986 to $5.6 billion by 1990, while standard cells will explode from $250 million at present to almost $4 billion by 1990, according to Dataquest; during the 1990s, the standard cell market should surpass that for gate arrays.

Programmable logic devices, the fourth ASIC segment, are the least complex and easiest to design. At about $230 million, their current market is on a par with that for standard cells, but the growth rate will not be as pronounced; by 1990, this market should be worth $1 billion.

ASIC vendors tend to specialize according to market segment. Full-custom circuits are manufactured by National Semiconductor (Santa Clara, Cal.), Texas Instruments (Dallas), Intel (Santa Clara, Cal.), and several Japanese firms. The leading producers of gate arrays and standard cells are LSI Logic and NCR Microelectronics (Fort Collins, Colo.), respectively. Standard cells are also offered by Zymos (Sunnyvale, Cal.) and VLSI Technology (San Jose, Cal.). Vendors of programmable logic devices include Monolithic Memories and Altera (both in Santa Clara, Cal.), and Xilinx (San Jose, Cal.).

In addition to the production of ASICs, some companies also provide services that enable customers to design, simulate, prototype, and test the circuits they plan to use. A quarter to a third of the 1985 market for each ASIC segment was composed of such service functions. These costs are likely to decrease as design equipment comes down in price. For example, "today's $100,000 CAE workstation will cost a half to a third as much by the end of the decade," says Andrew Prophet, senior industry analyst at Dataquest, "and by that time $100,000 will put the equivalent of a mainframe computer on the design engineer's desk." He adds that the proliferation of these workstations—produced by such firms as Valid Logic (Mountain View, Cal.) and Daisy Systems (Sunnyvale, Cal.)—will result in greater familiarity with gate array and standard cell designs.

"Customers have gotten into the design of their own circuits using gate arrays. Many are now ready to use more sophisticated and efficient design techniques, such as standard cells and silicon compilers."

Henri Jarrat, President VLSI Technology

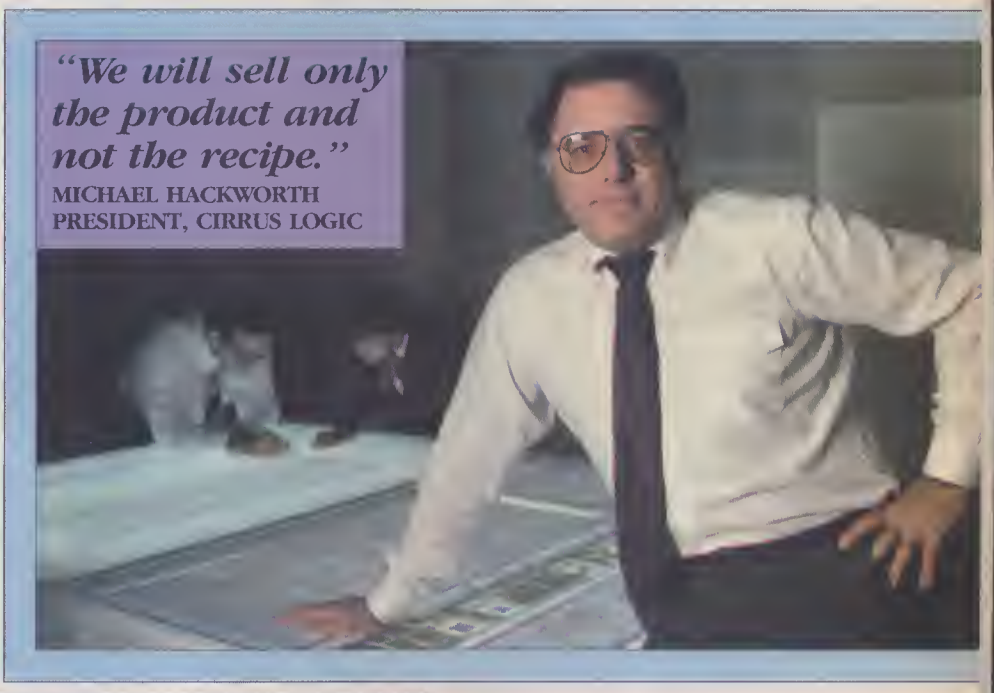
Silicon compilers, which permit users to synthesize ASICs from a description of the required functions, are also becoming an important design tool. One of the most serious challenges to vendors of such equipment—including Silicon Design Laboratories (Liberty Corner, N.J.), Silicon Compilers (Los Gatos, Cal.), and Seattle Silicon Technology (Bellevue, Wash.)—is to provide chip design software suitable for individuals not trained in semiconductor engineering. As ASIC design becomes more automated, Dataquest expects the number of workstations incorporating silicon compilers to rise from 100 last year to 10,000 by 1990, an installed base worth over $500 million.—***John Posa***

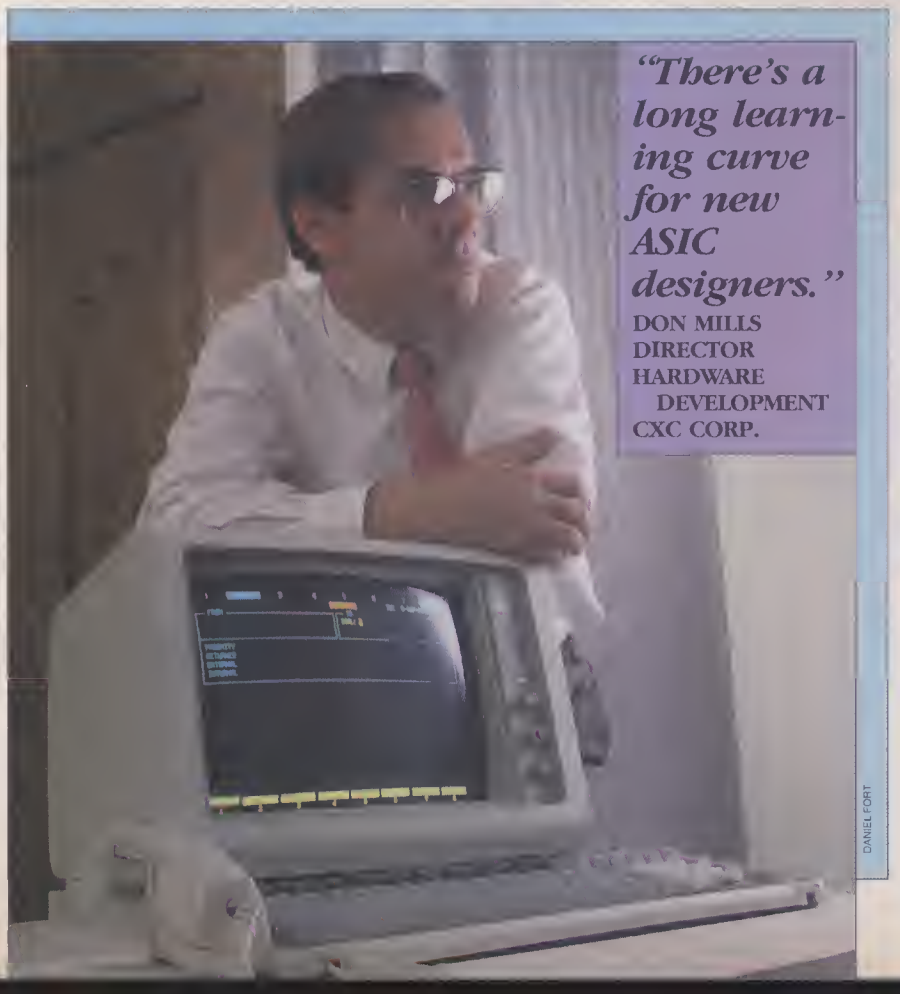
Semiconductor (San Jose, Cal.), and Xilinx (San Jose, Cal.). Altera offers a PC-based CAE system for programming its PLDs for as little as $2500, including an add-on board for the PC, logic design and device programming software, and a sample pair of PLDs. Altera's PLDs can be designed on an engineer's desktop in a matter of hours, according to David Laws, vice-president of marketing. "Eventually," says Rappaport, "programmable logic will be used for all but the densest designs to identify and correct functional errors. Metal-programmed parts, whether laser-zapped or conventional gate array, will be used for final checkout."

While PLDs leave everything in the hands of the design engineer, Cirrus Logic (Milpitas, Cal.) keeps its cards close to its chest with an unusual standard cell approach to ASICs. "We will sell only the product and not the recipe," says president Michael Hackworth. Cirrus Logic has developed a series of what the company terms "semistandard" ICs for data communications, graphics, and disk drive controllers. The company gives customers concept specifications for, say, a disk drive controller, similar to the engineering data sheets that semiconductor vendors provide for off-the-shelf devices such as microprocessors and memories. Customers can alter the specs to suit their purposes, changing operating frequency or input/output levels, for example. Cirrus Logic takes the revised specs and uses a proprietary specialized silicon compiler to produce a design that is optimized for the particular application. Cirrus Logic takes full responsibility for the design, testing, prototyping, and manufacture of the finished chip. The customer need not be familiar with IC design and is not required to learn how to use unfamiliar CAE tools. "Our customer's design tool is a very user-friendly ball-point pen," says Mark Singer, manager of marketing communications. Similar semistandard ICs are offered by Silicon Systems (Tustin, Cal.).

In part, the Cirrus Logic approach is a response to a major hurdle for novice ASIC designers—the considerable effort needed to become familiar with automated design tools. Many ASIC suppliers have set up design centers where customers can work on the vendor's own computers and receive immediate assistance with problems as the design work progresses. When Don Mills, director of hardware development for PBX maker CXC Corp. (Irvine, Cal.), decided to develop some standard cell circuits for a new generation of PBX equipment, he decided to do so at one of NCR's design centers. "Everything went pretty smoothly on that first project," he recalls. "But we had a much longer learning curve on the second project when we decided to use our own workstation." Not only did CXC's engineers take longer to learn how to use the schematic entry and simulation software, but the Mentor Graphics workstation, an early model, had limited capacity and was too slow for the 5000-gate circuits under development, thus further extending the design time.

Recognizing that inexperienced designers often have difficulty learning to use the current generation of tools, some ASIC firms are spending at least as much on software development as on improving their manufacturing processes. "The ASIC vendor who doesn't will not survive," claims An-





drew Haines, ASIC marketing manager for VLSI Technology.

In this spirit, several ASIC companies—especially VLSI Technology, Waferscale Integration (Fremont, Cal.), Zymos, and England's Plessey Co.—are attempting to bring sophisticated VLSI designs within the reach of more system engineers by offering larger and more complex cells. These "megacells" are VLSI elements such as a core microprocessor, a peripheral controller, or a complete communications modem predesigned within one large cell. Thus the ASIC designer is spared the effort of designing the logic for, say, a modem, and need only change such specifications as speed and word length to obtain the desired function. A relatively straightforward compiler is used to customize the megacells, resulting in shorter design time and a more efficient use of silicon. Plessey likens its approach to the spreadsheet used in business for financial modeling. In essence, all a designer must do to set the parameters of a megacell is insert numbers into a "silicon spreadsheet."

Zymos has taken the megacell idea even farther with the concept of a "silicon template," a complete computer system design on a chip. The system engineer combines several megacells that have been completely designed, simulated, and laid out, and then stored in a software library. As in the silicon spreadsheet approach, the designer can alter the parameters of the cells making up the system to improve overall performance or customize for a specialized application. Zymos, for example, developed an IBM PC/AT silicon template including most of the components (all except the microprocessor, the dynamic memory, the basic ROM, and the keyboard controller) on a 25,000-gate chip less than half an inch square. In effect, the number of chips in the PC is reduced from 90 to four, claims Robert Andrews, director of technical marketing for Zymos.

The megacell and the silicon template simplify the system design process; the engineer need not know in detail how to design the circuitry of a modem or a drive controller. The next stage in bringing ASIC design to a larger community of designers is probably the wider acceptance of silicon compilation—the automatic synthesis of ICs from a behavioral description of the system, as opposed to conventional design by entry of a logic schematic diagram. Although silicon compilation has been around in the academic world for several years, practical commercial compilers have only just begun to appear. In 1985, approximately 100 workstations with silicon compilation capability were shipped, according to Dataquest, but sales are expected to triple in 1986 and continue to triple through the end of the decade.

The early silicon compilers were expensive and aimed more at the sophisticated IC designer than the system engineer. The first Genesil silicon compiler from Silicon Compilers, Inc. (San Jose, Cal.), required a large VAX computer and cost more than $100,000 per terminal. Silicon Compilers and other vendors such as VLSI Technology, Seattle Silicon Technology (Bellevue, Wash.), and Silicon Design Laboratories (Liberty Corner, N.J.) are now making their compilers available on less expensive engineering workstations. None has gone quite so far as Lattice Logic Ltd. (Edinburgh, Scotland), which recently introduced its Silicon Compiler Spreadsheet, a package that runs on an IBM PC/AT with an added 32-bit coprocessor. The Silicon Compiler Spreadsheet is restricted to circuits containing fewer than 5000 gates. But since most of today's ASICs fall within that limit, many industry observers expect the spreadsheet concept to proliferate.

"The ASIC vendor who doesn't spend as much on software as on manufacturing will not survive."

While silicon compilers are currently suited only to digital circuit design, the interfaces required between computers and industrial controls or instruments are analog. Thus analog functions are becoming an increasingly important part of many semicustom chips. "By 1990 about half of all semicustom chips will contain some analog circuitry," says Cindy Thames, a vice-president of The Technology Research Group. "Customers will choose libraries and vendors on their ability to do analog." Although demand for analog capability is increasing, the tools for automating the design of analog circuits are not as mature as those for digital IC design. Not only are analog circuits such as operational amplifiers and analog-to-digital convertors more difficult to design as integrated circuits, because of their requirements for linearity and precision, but high-performance analog chips are more sensitive to electrical interference and thermal effects than all-digital chips.

One solution is to use analog standard cells rather than attempting to design at the transistor level. NCR and Gould AMI (Santa Clara, Cal.) both offer some analog standard cells. Probably the most extensive library is provided by a relative newcomer, Sierra Semiconductor (San Jose, Cal.), which offers over 30 analog cells compatible with a 2-micron production process. Sierra can also combine digital, analog, and EEPROM (electrically erasable programmable ROM) technology on the same chip, says Don MacLennan, Sierra's director of custom product marketing. The EEPROM cells provide replacements for potentiometers, switches, and other means of calibrating and programming system functions, important for analog circuits. Sierra is working with Seattle Silicon Technology to incorporate analog functions into the latter's Concorde silicon compiler, further simplifying the design process for system engineers who wish to combine digital and analog functions.

Most industry observers expect the automated tools required for ASIC design to become easier to use and faster as the ASIC market expands. "Silicon compilation is not yet of age," says Andrew Kessler, an analyst with PaineWebber (New York). "But it's becoming well used for military applications where performance is paramount and efficient use of silicon is a factor. That body of experience will result in improvements in silicon compilers."

The acceptance of silicon compilation may have been slowed by the cost of both hardware and software. But the coming generation of 32-bit personal computers based on the Intel 80386 microprocessor will bring powerful workstations within the reach of many more system engineers. Such machines will be capable of handling the massive computation and large memory requirements of silicon compilers and cell libraries.

Ideally, system designers would like to be able to produce circuits as efficient as the full-custom designs generated by experienced IC designers. "We're not too far away from seeing tools based on artificial intelligence," says Sierra Semiconductor's MacLennan. "Then we'll be able to bring the best IC designers' know-how to the system engineer." Already Gould AMI and the U.S. Army's Electronic Technology and Device Laboratory (Fort Monmouth, N.J.) are working on a silicon compiler that uses a stored base of expert design knowledge. When such knowledge can be captured in every system engineer's workstation, ASIC design could well become the method of choice for electronic systems. □

Jeffrey Bairstow is a senior editor of HIGH TECHNOLOGY.

For further information see **RESOURCES**, *p. 69.*

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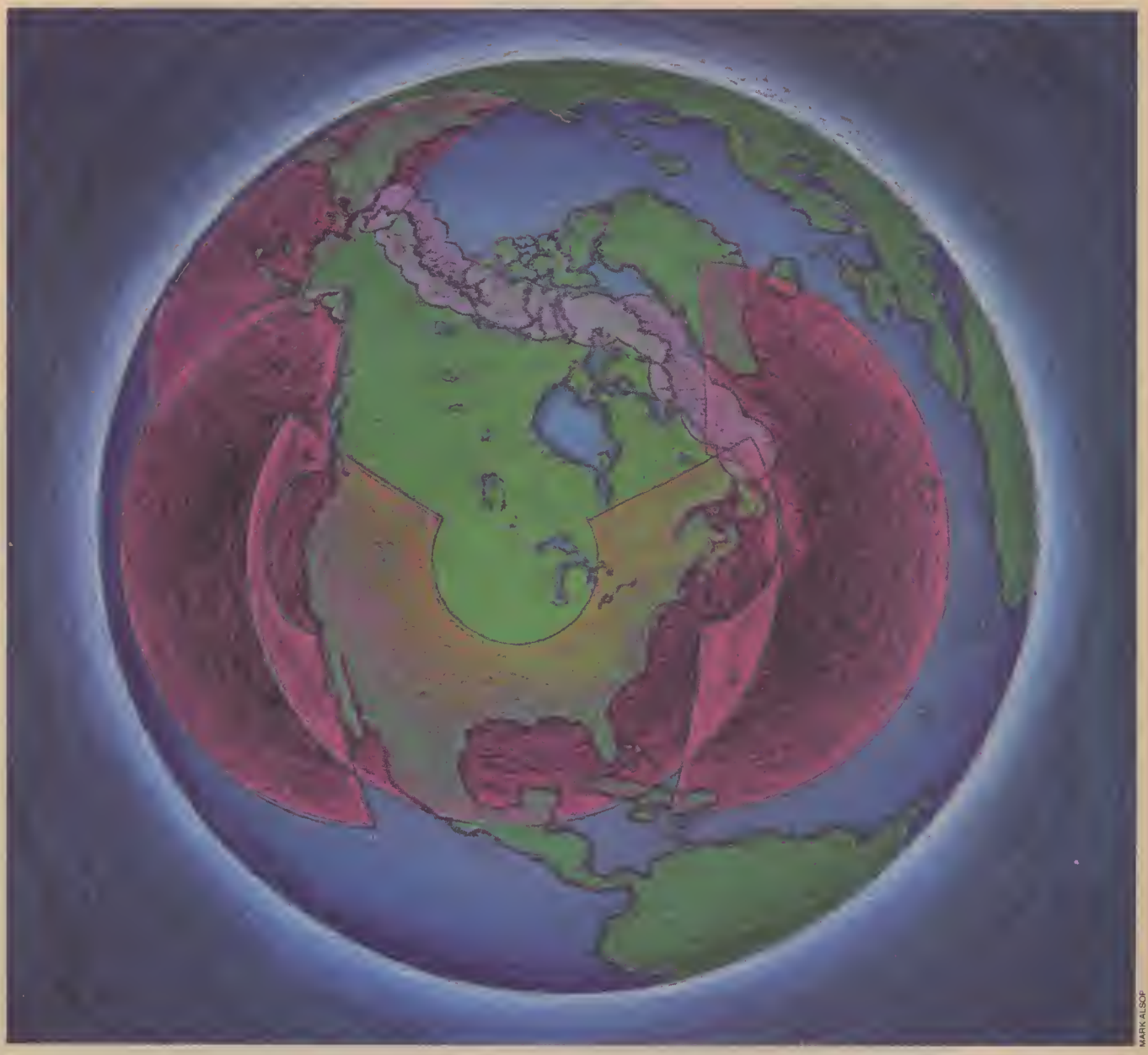
SHARPER EYES

Converting the U.S. radar shield to solid state will improve coverage and cut operating costs

by Peter Gwynne

North America's radar barrier, erected three decades ago to detect approaching enemy planes and missiles, is undergoing a major overhaul. With some help from U.S. allies, the Department of Defense is upgrading the ballistic missile early warning system (BMEWS) and phased array warning system (Pave Paws), which seek evidence of incoming ICBMs thousands of miles away in space; refurbishing the north-pointing sector of the old Distant Early Warning (DEW) line, which looks across the Arctic Ocean for signs of enemy bombers and cruise missiles; and erecting an entirely new over-the-horizon backscatter (OTH/B) system to spot air-breathing craft, as far away as 1800 nautical miles, approaching U.S. shores from the east, west, and south.

The Air Force's Electronic Systems Division (ESD), based at Hanscom Field near Boston, has already started to parcel out the work on the $4.5 billion



MARK ALSOP

ON THE SKY

upgrade. Raytheon's Equipment Division (Wayland, Mass.) has a 22-month contract worth $409 million to improve the two initial Pave Paws radars that it installed seven years ago and to build two more.*

Raytheon has also won prime responsibility for enhancing the BMEWS radars at Thule in Greenland and Fylingdales in the United Kingdom. General Electric (Syracuse, N.Y.) has the initial OTH contract—to install the system's eastward-pointing segment in Maine. GE is also building long-range radars that, together with short-range stations being developed by Sperry (Great Neck, N.Y.), will peer across the Arctic wastes as components of the North Warning System (NWS), essentially taking over the DEW line's mission of monitoring northern approaches to the continent.

Other contracts remain to be awarded. ESD has received preliminary approval for upgrading the third prong of the BMEWS system, probably in Clear, Alaska. And the division has just started planning work for the south-pointing and Alaskan segments of the over-the-horizon radar. Air Force officials

*"Pave" refers to the Air Force Office that oversees the program; acronym buffs decided on the phrase "perimeter acquisition vehicle entry" to fit the initials. "Paws" stands for "phased array warning system."

Overlapping segments of radar coverage will upgrade North America's early warning systems. Map on opposite page shows the reach of Pave Paws (yellow) and the Ballistic Missile Early Warning System (tan). Map above represents ranges of North Warning System (purple), which will spot bombers and cruise missiles, and over-the-horizon radar (pink).

expect all the radar fences to be in place in the early 1990s. Once operating, the system should last for at least 20 years.

The need for improved radar protection stems partly from the advancing age of the original DEW line and ballistic missile early warning system. Not only is this setup deteriorating; its technology, replete with 1950s-vintage vacuum tubes, makes it increasingly difficult to obtain spare parts.

Cost also enters the equation. In addition to plugging holes in the old DEW line, the overhaul will significantly reduce the day-to-day expenses of detecting incoming threats, mainly by minimizing the number of people needed to staff radar installations. Three-quarters of the 52 radars in the North Warning System, for example, will be unmanned; the other 13 will have minimal crews. The predicted financial result: annual operational and maintenance costs for NWS will fall from $110 million to $65 million.

Just as critical a reason for the upgrade is the Soviet Union's improved capacity to deliver nuclear warheads. Intercontinental ballistic missiles that travel at hypersonic speeds over a range of 10,000 miles have emerged as routine components of the Soviet arsenal, as have cruise missiles and high tech bombers. And the Soviet Union hasn't improved just the quality of its weapons carriers; it has developed the potential to scramble enough aircraft and missiles to overwhelm the rotating dishes that for many years were synonymous with the word "radar." While perfectly adequate for such tasks as air traffic control, mechanically steered radars are too slow and too unreliable for the projected needs of national defense in the 1990s. So the new and upgraded protective systems will all use phased array radars—static banks containing up to several thousand small, identical antennas that generate and electronically steer a single powerful radar beam.

Because phased arrays have no moving parts, they last much longer than conventional radars.

Phased array radars can scan large segments of the sky in microseconds rather than the seconds taken by conventional radars. And unlike their mechanical counterparts, they can track large numbers of missiles attacking from different directions. According to Eli Brookner, a radar consultant for Raytheon, a single phased array system can do what previously might have required a battery of mechanically steered dishes.

Because phased array radars don't rotate physically, there are no moving parts to wear out or break down. Builders of the NWS, for example, expect that a failure severe enough to interrupt the data flow will occur only once every six months. The current DEW line has one such failure every 200 hours. Initial plans for the Pave Paws array at Otis AFB on Cape Cod, Mass., included a round-the-clock crew of several maintenance personnel to replace antenna modules that malfunctioned. But because the actual failure rate is no more than about two-thirds of a module per day, and because each face can lose 132 of its nearly 2000 antennas without compromising its power or accuracy, the maintenance staff now consists of just three people who check the antennas once a week.

The key to a phased array radar is the matching of the microwave signals departing from each of its many antennas. All the signals originate from a central oscillator; they are amplified and then fed to the individual antennas. A short distance in front of the bank of antennas, the signals from each antenna link up to form a single beam. If all the signals are in phase as they leave their antennas, the beam travels straight ahead. If the signals are delayed by brief amounts of time that increase consistently across the face, the beam forms at an angle to the perpendicular—an angle whose magnitude depends on the amounts of the delays. The time delays mimic the physical rotation of a mechanically steered

Thrusting radar beams toward the Atlantic Ocean, the Pave Paws facility at Cape Cod's Otis AFB maintains a round-the-clock watch for submarine-launched ballistic missiles.

radar. The effect happens in reverse as the echoes from planes and missiles return to the array, yielding interpretable images on displays. Controlled introduction of the timing delays—a process known as phase lag steering—enables the beam from a single flat bank of antennas to sweep across a 120° field of view in just a few microseconds.

The first major phased array radars to join the U.S. curtain of protection were two Pave Paws systems that went on the air at Otis AFB and Beale AFB near Sacramento, Cal., in 1979. Unlike previous systems, each Pave Paws radar can track hundreds of missiles simultaneously. Pave Paws' focusing precision is equally impressive. According to William Comisky, Raytheon's marketing manager for phased array systems, the Otis radar could track a metal basketball over St. Louis or a Volkswagen over Spain.

The radar overhaul will greatly reduce the cost of detecting airborne threats to North America.

The original Pave Paws radars are both two-sided systems in which each flat face contains 1792 active antenna elements and 885 dummy elements, whose antennas are isolated from the system's computers but can eventually be linked up to increase the system's detection capacity. In addition, the number of elements can be doubled to 5354 by covering the available 103 feet in height and width per face, rather than the 73 feet now used, with the 12- by 8-inch transmitter/receiver modules. Each side can sweep independently across an angle of 120°; simple electronic engineering that links data from the two faces thus gives each Pave Paws radar 240° of horizontal coverage, at elevations between 3° and 85°.

Radar signals produced by the experimental over-the-horizon transmitter in Maine bounce off the ionosphere and monitor approaching aircraft and cruise missiles far beyond the line of sight.

Pave Paws is entirely solid state. Instead of vacuum tubes, thousands of power transistors—each smaller than a penny—control the system's energy. Most of that energy is stored briefly in large capacitors linked up with the solid-state modules that are attached to each antenna. The capacitors provide 95% of the power of each radar pulse emitted by an antenna.

Pave Paws radars operate in three major modes: searching, verifying, and tracking. The choice of mode determines the length of the pulses emitted by the antennas, explains Lt. Col. Gayle White, who as commander of the Cape Cod Air Force Station oversees the Otis installation. Most of the Otis radar's work is devoted to tracking satellites and U.S. missile tests. But the programs, and the operators, are primed to react immediately to evidence that an unanticipated object has penetrated the instrument's radar fence.

Because its coverage overlaps slightly with that of the BMEWS sites in Greenland and Britain, says Lt. Col. George V. Boyd III, director of Pave Paws, the Otis radar does not need any boost in power during the upgrade. Improvements will consist merely of providing more modern computers from Control Data Corp. (Minneapolis) and attendant software. The Beale AFB radar, which does not overlap any of the BMEWS coverage, will undergo more profound alterations. By doubling its number of active antennas to 3584, the refurbishing will give the radar four times its present power.

In addition, two new Pave Paws facilities are now under construction, at Robins AFB in Georgia and near Goodfellow AFB in Texas, to monitor areas of the Gulf of Mexico and the Pacific beyond the reach of the first two radars. The Goodfellow facility will have the same power as the Otis system. The Robins facility, because it will take over space tracking now performed at Eglin AFB in Florida, will eventually possess eight times that power, derived from 5354 active antennas on each of its two faces. The Air Force expects to start using the Robins site—in a low-power form—in November, and the Goodfellow radar next May.

Phased array radars will also replace the old-style rotating BMEWS radars that were erected at Thule, Fyling-

Military radar: Large companies hold sway

The U.S. missile and bomber detection systems currently being upgraded are part of a larger military radar market that can be divided into two broad segments: airborne, and ground- and ship-based. Airborne radar includes missile fire-control systems aboard fighter aircraft, surveillance and reconnaissance radars that locate and map ground targets, altimeter and weather radars, and radar incorporated into missiles themselves. This segment should grow from $2.5 billion in fiscal 1986 to $3.2 billion in 1990, according to market research firm Frost & Sullivan (New York). The ground- and ship-based segment, including the Air Force's strategic defense networks and smaller air surveillance and fire control systems, should hover around $4 billion annually through 1989.

Both segments are dominated by giant aerospace and defense electronics companies, particularly Westinghouse Electronic (Baltimore), Hughes Aircraft of El Segundo, Cal. (now part of General Motors), General Electric (Utica, N.Y.), Raytheon (Bedford, Mass.), Sperry Electronic Systems (Great Neck, N.Y.), and RCA (New York), which has been purchased by GE.

The Gramm-Rudman-Hollings legislation aimed at reducing the federal deficit will have a varying impact on funding for radar programs. For example, "radar manufacturers that have a large base of installed systems can continue to count on a steady market for repairs and replacement parts, which comprise most radar sales," says Phillip R. Brannon, a vice-president at Merrill Lynch (New York). In addition, funding cuts are unlikely for improvements to the large-scale radar systems intended to warn U.S. forces about incoming missiles and bombers.

But new naval and aircraft-based tactical radar systems may feel the pinch of Gramm-Rudman as the technologically sophisticated vehicles for which they are intended come under increased congressional scrutiny. The Navy, for instance, plans to expand its combat fleet from 555 to 600 ships, which should increase demand for shipboard air-surveillance and fire-control radar systems. However, "adding another battle group would require incredible expense to build and maintain the ships, along with the costs of fuel, supplies, and sailors," says Robert Hanisee, president of Seidler Amdec Securities (Los Angeles). "In a period of budget austerity, the Navy is unlikely to reach its goal, though it may build some ships such as the DDGX destroyer at a reduced production rate."

MARK STEPHENSON

"As radar funding is reduced, major contractors are bidding tighter, cutting profit margins, and going after market slices in which they are not currently involved."

Robert Hanisee, President Seidler Amdec Securities

But even if funding for new ships or airplanes is cut back, the Pentagon is continually upgrading existing weapons inventories to keep pace with current estimates of threats to national security. Often, the same radar developer who loses a contract for installing new systems sees the funds diverted into a contract for updating older systems.

Competitive prospects also vary among radar programs. Competition for prime contracts in the strategic radar programs is likely to be limited, because firms are reluctant to put substantial resources into competing for projects in areas already dominated by a handful of major contractors. For example, only Raytheon submitted a bid for a phased-array radar unit in England that is part of the BMEWS system, although the Air Force attempted to obtain bids from additional sources. Raytheon had previously won the contract for constructing a similar BMEWS radar in Greenland and is a major player in the Pave Paws network.

By contrast, competition in the tactical radar market is significant among companies of all sizes. Smaller firms, in particular, have carved out important positions in niche markets. Sanders Associates (Nashua, N.H.), for example, plays an important role in providing radar jamming equipment to the Air Force and Navy; Varian Associates (Palo Alto, Cal.) supplies klystron and traveling wave tubes, and other electronic devices for radar systems; and TSC (Santa Monica, Cal.) has developed a bistatic radar system, which physically separates the transmitter from the receiver to lower the possibility of interception or jamming.

But market segments that show high growth potential tend to get absorbed by large companies, particularly in a time of budget cutbacks, as illustrated by Westinghouse's purchase of TSC last year and Lockheed's recent takeover of Sanders. "Gramm-Rudman legislation has heightened competition in the radar arena," says William Chanatry, manager of surveillance systems programs at GE. "As major suppliers reposition themselves in the marketplace, we could be merging into each other's niches."

—Carol Tomme Thiel

dales, and Clear in the 1960s and upgraded in the 1970s. The Thule work, which will cost about $95 million, involves erecting a phased array station similar to Pave Paws atop a tracking pedestal originally built for a mechanical radar. The pedestal, reinforced with 200,000 tons of steel, contains refrigeration systems beneath it to keep the surrounding permafrost frozen. Each of the radar's two 84-foot-square faces will contain 1792 active modules and the same number of dummies. On completion late next year, the system will be roughly twice as powerful as the Pave Paws at Otis AFB. The single phased array will replace an assemblage of four detectors to spot approaching objects as early as possible and one tracking radar to keep tabs on them.

Meanwhile, negotiations are well under way among ESD, Raytheon, and the British government for the upgrade of the Fylingdales site, which now contains three mechanical tracking radars. This plan involves something new: a three-sided phased array that will monitor a complete circle. The main change to accommodate that geometry will be an increase in the size of the signal processors. The Thule and Pave Paws radars require only 240° of coverage because they look outward from the North American continent.

Finally, ESD is outlining preliminary plans to upgrade the BMEWS site at Clear, in the Aleutians, which now contains three mechanical detector radars and one tracker. However, says Maj. Alan C. Jost, BMEWS deputy program director, a firm decision to move ahead with that work is not expected for two to three years.

There is one major difference between the new BMEWS and Pave Paws. Because BMEWS concentrates predominantly on land-based missiles, which can be delivered in far greater numbers than those launched from the sea, it has to deal with far more complexity. "If you regard Pave Paws as a juggler who handles three balls, BMEWS is the same juggler handling about a thousand," says Jost. As a result, BMEWS contains more sophisticated signal processing capabilities.

Whatever its complexity, the phased array approach used in Pave Paws and BMEWS is familiar technology. By contrast, "OTH/B is an entirely new capability," declares Col. James A. Lee, director of the over-the-horizon radar system. "We have never before been able to look beyond the line of sight for atmospheric vehicles." By bouncing high-frequency radar beams and their reflections (backscatter) off one of the lower layers of the ionosphere—about 200 miles up—OTH radars will be able to detect aircraft and cruise missiles flying through a corridor that stretches between 500 and 1800 nautical miles from North American shores, bounded only by the wavetops. "The good news with the system is that you can't underfly it," says Major Edward F. Pleuler, site implementation director for the East Coast OTH/B system, located at Maine's Bangor International Airport. "The bad news is that it can't tell you the height of objects it detects."

JON GOELL

Over-the-horizon radar provides an entirely new detection capability, says program director Col. James A. Lee.

It can, however, tell the speed, because it's a doppler radar. In fact the system searches for what Pleuler calls "offsets" in speed—between objects under surveillance and the background of the ocean waves. Theoretically, the system could detect ships at sea, as well as aircraft and low-flying missiles. But in practice, ships travel so slowly relative to the ocean that their offsets are lost in the background noise.

The basic unit of OTH radar is a combination of transmitter, receiver, and operations center that oversees a horizontal sector of 60°, covering more than 1.5 million square miles of airspace. The transmitting antennas stretch almost 4000 feet horizontally, in sections ranging from 35 to 135 feet in height; the various sections transmit different frequencies, from 5 to 28 megahertz. The receiving antennas are 246-element arrays almost 5000 feet long and 65 feet high. To prevent the waves emitted by the transmitter along the ground from swamping out the received beam, the transmitting and receiving antennas must be separated by about 100 miles. A loran-C timing system, which relies on precisely timed pulses emitted by specialized transmitting stations, keeps the separated sites in synchrony.

The program, costing about $1.2 billion, should be completed in the early 1990s. At that point, a total of 12 sectors in four central locations will monitor three sides of the North American continent for low-flying aircraft and cruise missiles at ranges of up to 10 times the reach of conventional air surveillance radars. Transmitter and receiver sites, both selected and sought, are predominantly rural. To maximize the OTH radars' performance, explains Lee, "you tend to put the receiver and transmitter away from man-made noise."

The initial facility, designed to provide the East Coast with 180° of protective coverage, will consist of three transmitters in Moscow, Me., three receivers 110 miles to the southeast in Columbia Falls, Me., and an operations center in Bangor, about midway between the two. A similar West Coast grouping will contain transmitters near Christmas Valley, Ore., receivers about 100 miles away at Alturas, Cal., and an operations center at Mt. Home Air Force Base in Idaho. The Air Force has chosen Grand Forks AFB in North Dakota as operations center for a grouping of four sectors that will face south and fill in holes left by the east- and west-facing systems, and Elmendorf AFB outside Anchorage, Alaska, for a northwest-facing facility with two sectors. However, site selection is still under way for those segments' transmitters and receivers.

Each sector is divided into a series of fan-shaped regions about 500 nautical

miles deep and covering a 7½° angle. Bounced off the ionosphere, the OTH beam focuses on each region in turn. As it scans, the beam creates a "radar barrier" by illuminating eight such regions for two seconds at a time, in such a way that all air-breathing vehicles approaching the U.S. must pass through the beam. During each scan, the beam can also be directed to illuminate three extra 7½° regions, to follow the path of a single suspicious airplane, for example, or to keep a specific segment under continuous surveillance.

The wild card in the setup is the ionosphere itself. The electromagnetic clutter that auroras produce in the ionosphere in the direction of magnetic north puts a north-facing OTH system out of the question for the present. Even in other directions, the ionosphere "is changing all the time," complains Maj. Robert Coman of the Air Weather Service, who is working with Pleuler's group at Bangor. "The time of day, the season, and the solar cycle all affect it." Fortunately, the changes occur slowly enough for radar operators to compensate for them by altering the frequencies and wave forms of transmissions. At sunrise, the most difficult transition time, transmitter operators typically have to shift frequencies by 1 megahertz every 10 minutes.

Research is under way to overcome the difficulty in north-facing over-the-horizon coverage; but for the foreseeable future the gap will be filled by the North Warning System (NWS), whose $1.3 billion cost will be shared by the U.S. and Canada on a roughly 60-40 basis. Transmitting at 1.2 gigahertz—a frequency unaffected by auroral interference (but not suited to OTH/B because it doesn't bounce of the ionosphere)—the system will monitor the short-cut approach to North America over the North Pole. The joint U.S.–Canadian project will consist of 13 lightly manned long-range radar stations from General Electric and 39 automatic short-range radars built by Sperry. The long-range radars are scheduled to start their surveillance in the summer of 1988, the short-range devices in 1991 and 1992.

For the NWS, long-range is a relative term, indicating a reach of about 200 miles. The short-range radars, with an outer limit of 60 miles, will fill in the gaps between long-range stations. NWS radars also differ from others in the new curtain of protection in that they are two-dimensional rather than three-dimensional phased arrays. The long-range radars obtain their third dimension of coverage by physically rotating inside radomes—which reduces their lifetimes—and the static, cylindrical short-range instruments cannot monitor traffic above 10,000 feet.

Those limitations are not critical, says Col. Roger L. Gounaud, Jr., former director of the North Warning System. Even with their moving parts, the long-range radars are expected to be appreciably more reliable than the DEW line radars they will replace. And since the main purpose of the short-range radars will be to limit the ability of bombers to fly underneath the radar fence erected by the long-range radars, their lack of high-altitude coverage will not compromise the system. Indeed, the new radars may detect too much rather than too little. Because of their precision at low altitude, says Gounaud, "one of our concerns is that the radars may see individual birds." The fact that the radars are doppler instruments will help, however; echoes should quickly peg birds as objects flying too slowly to represent any threat to national security.

The new and upgraded forms of radar protection raise an important political issue, however: How does the U.S. start to operate major parts of the overall defensive curtain without breaking the 1972 antiballistic missile (ABM) treaty? Under the terms of the treaty, "each party undertakes not to deploy ABM systems for a defense of the territory of the country, and not to provide a base for such defense." Hence the agreement implies two conditions for new phased array radars designed to warn of incoming ballistic missiles. They must be "oriented outward" from the nation they protect, and located on the periphery of that nation, where they cannot be so heavily defended that they can become part of a ballistic missile defense prohibited by the ABM treaty. Quoting those conditions, the Reagan Administration recently objected to a large phased array radar under construction near Krasnoyarsk, deep in the Siberian hinterland. In turn, the Soviets have raised questions of their own about the upgraded Pave Paws and BMEWs systems.

The U.S. must answer a major political question: How can it operate its new and upgraded radars without breaking the 1972 ABM treaty?

Once it is completed, the Soviets assert, the four-unit Pave Paws system will occupy locations similar to those planned for the Safeguard antiballistic missile system of the early 1970s. While the Pave Paws facilities are plainly not "battle management radars"—units that, because they can define individual incoming objects, are restricted by the ABM treaty—Soviet diplomats argue that they could be linked together in a territorial defense system forbidden by the treaty. That argument receives short shrift from the U.S. "The similarity between Pave Paws and Safeguard radars is that all large phased array radars basically look alike," says Air Force Lt. Col. Terry Thornton, a project officer for verification in the Arms Control and Disarmament Agency. "What Pave Paws radars do is say that there's a missile coming, and that it will impact at a certain point."

The Soviets object to the BMEWS upgrade on the grounds that the radars to be erected in Greenland and the U.K. are distant from American borders. "Our justification for them," counters Thornton, "is that we had sites there at the time the ABM treaty was signed. There is no restriction on upgrading of sites. We consider that they're 'grandfathered.' " Unstated so far, according to Michael Krepon of the Carnegie Endowment for International Peace in Washington, D.C., is the fact that while the ABM treaty details strict conditions for upgrading existing ABM radars, it says nothing about early warning radars. "And it's hard to argue that [the BMEWS devices] are anything but early warning radars."

Many U.S. observers regard the Soviet complaints about Pave Paws and BMEWS as nothing more than tit-for-tat responses to American charges that the Krasnoyarsk radar violates the ABM treaty. "You can find a Soviet [counter-complaint in] response to all our complaints about their noncompliance," argues Thornton. That tactic, of course, is hardly novel in the world of diplomatic negotiations. As Krepon sees it, "you try to hold the other side to a very strict accounting, while giving yourself as much leeway as possible. That's a fair game." But he contends that the diplomatic parrying will have little effect on plans for upgraded systems. "Early warning of ballistic missile attack is a very high-priority requirement for both sides," says Krepon. "They're just not going to allow quibbles to get in the way of putting new systems up to replace old ones." □

Peter Gwynne is a senior editor of HIGH TECHNOLOGY.

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FACTORY-BUILT HOMES: BEYOND THE TICKY-TACKY

Japanese and Swedish assembly lines produce low-cost, high-quality housing

The recent arrival on U.S. shores of homes produced in Swedish factories may signal a sweeping change in the way houses are built. To most Americans, manufactured housing suggests "prefab," which conjures up images of flimsy metal-walled dwellings often found in mobile-home parks. But the Swedes are blending craftsmanship with automation, resulting in a far better product than the stereotypical prefab box. In Japan, meanwhile, consumers can customize the design of their manufactured homes via computer.

Factory assembly of wall panels for housing began in Sweden more than 100 years ago to facilitate building during the short, cold days of the Scandinavian winter. The technique got a boost during World War II, when the shortage of workers created a need for more efficient use of manpower.

The stringent energy efficiency standards instituted by the Swedish government in response to the energy crisis of the early 1970s turned out to be a boon to the manufactured housing industry, since the quality control possible in the factory made it easier to meet these standards. By mid-decade, about 30% of new Swedish housing was factory built.

The average Swedish manufactured home has R-33 insulation in the walls and R-47 in the ceilings (the higher the R-value, the lower the heat loss) and allows only 0.2 air changes per hour, according to Lee Schipper of the Lawrence Berkeley National Laboratory, who led a study of Swedish housebuilding techniques. By contrast, the typical new American home has values of R-17 and R-19, and 0.4 air changes. By 1985, more than 90% of new Swedish housing was factory-built, according to Paul Kando, director of the Center for the House (Washington, D.C.), a nonprofit organization that studies new housing concepts. Kando characterizes the high-quality Swedish process as "factory crafting" to distinguish it from manufactured housing as practiced in the U.S.

Manufactured housing is not alien to the U.S., of course. Of the 1.7 million homes built in the U.S. in 1985, about 30% used premade panels and 4% used room-size modules, according to Linda Parrish of the National Association of Home Builders. The difference is that the U.S. manufactured housing industry aims at the low end of the market; the primary goal is to produce a highly standardized product at a low cost. "We see the home as a consumer product," says Austin Guirlinger, president of Cardinal Industries (Columbus, Ohio). "We'll produce them like cars, and we'll sell them that way." Indeed, Cardinal—the only U.S. company to market modular houses nationwide—now makes 12,000 units a year at factories modeled after automobile plants, according to Guirlinger.

The emphasis at Cardinal is on efficiency rather than elegance or flexibility. Where the Swedes employ craftsmen to carefully miter joints, Cardinal conceals the roughly cut joints with a plastic cover. The Swedes use hardwood moldings, while Cardinal uses vinyl-coated fiberboard. Cardinal offers limited design choices, and no variation from its 12×24–foot module. This approach suits the market: most of Cardinal's construction becomes rental housing or motels, where tenants are often not finicky about styling. The company is beginning to sell single-family homes, though, and now uses computer-aided design to allow more variety.

Such flexibility already exists in Japan, where computer-aided design and manufacturing systems allow automated production without sacrificing

An automobile-style assembly line mass-produces identical wall panels at Cardinal Industries. More advanced factories in Sweden and Japan build structures with greater variety.

by Kevin Finneran

Home-building, Swedish style: A factory-made wall unit (left), complete with windows and insulation, is lowered into place, with a rubber gasket on the foundation forming an airtight seal. A dormer window unit (right) adds a custom touch, relieving the uniformity usually associated with prefab housing.

The house that Sven built

A Swedish home factory looks nothing like a traditional building site. At the Anebyhus plant in Aneby, construction begins with logs from nearby forests. At the sawmill, sensors scan each log, measuring its length and diameter; using this information, a computer calculates the optimum way to cut in order to yield the greatest supply of usable lumber. Just before the cut begins, a laser projects a line of light indicating the saw's path; an operator adjusts the cutting blades accordingly. Machines sort the cut lumber and deliver it to the kilns, where it is dried to a water content of 10–12%—resulting in less warping and splitting than the 15–19% water levels common in U.S. lumber.

In the factory, boards are fed automatically into a jig that holds them in place for the assembly of wall panels. Automatic pneumatic screwdrivers descend and quickly secure the frame. Mounted on an automated tilt table, the jig moves down the assembly line, where workers add doors and windows that are sealed with gaskets for an airtight fit. Other workers slip precut pieces of insulation into the walls. The conveyor belt moves the jig to the next station, where two workers attach a plastic vapor barrier. An inner layer of framing adds space for additional insulation and makes it possible to install wiring without piercing the vapor barrier. Finally, robot screwdrivers attach the exterior siding and interior gypsum board. In other parts of the factory, similar assembly lines produce floors and roofs.

Next comes the most distinctive characteristic of Swedish manufactured housing. Skilled woodworkers use precision tools to complete the trim and finish. The automated jigs and the comfortable indoor conditions make it easier to do careful work. The resulting quality shows: Doors close with the reassuring whoosh of an airtight seal, and windows have essentially no leakage, even in winds up to 50 mph. Dormers and spiral wooden stairways give the feel of a custom-built house.

Wall, roof, and floor panels are tightly wrapped in plastic for delivery to the building site. A crane lifts the panels onto a concrete foundation topped with a rubber gasket, which forms an airtight seal. A three-person crew along with a crane operator assembles the shell of the house in one day. Some Swedish companies produce smaller wall panels that enable the do-it-yourself builder to erect a house in about three days, without a crane. Kitchens and bathrooms are supplied as complete room modules for quick installation.

design flexibility. A house-hunter can look at numerous model homes and then sit down at a computer console with a salesman, mixing and matching options to produce up to 2000 different homes. When the design choices are made, the information is relayed to a computer at the factory and the house starts down the assembly line. Production of panels can take as little as 45 minutes, and the buyer can move into the house 30–40 days after ordering it. (Japanese regulations require plumbing and wiring to be installed on site, slowing construction time.)

The Japanese began manufacturing homes in earnest only in 1975, when the government introduced the House 55 program, aimed at lowering the cost of home construction to 55% of that year's level. Factory-built homes now account for 15% of new construction, reports Donald Carlson, editor of the *Automation in Housing* newsletter. Sekisui House, Misawa Homes, and Daiwa House each produce up to 40,000 homes a year in highly automated plants, according to Carlson.

As with other Japanese products, quality standards are demanding. The largest manufacturers have special test facilities that subject manufac-

tured homes to driving rain, 140-mile-per-hour winds, and earthquakes. (Movie companies often rent the test facilities to film storm scenes.) Wood is scarce, so frames are welded together from steel. And Misawa Homes has developed a strong, light, and thermally tight ceramic wall material; it is cheaper and easier to build a house by assembling panels of this stuff than by constructing the conventional sandwich of exterior siding, insulation, wooden framing, and interior plaster board.

Neither Swedish nor Japanese housing is exactly suited to American tastes. Although Swedish woodwork and cabinetry will appeal to Americans, Kando says that "Swedish exteriors are unimaginative and lack the 'street appeal' that U.S. homebuyers are looking for." Swedish bedrooms, bathrooms, and kitchens are small by U.S. standards. Japanese houses are also much smaller than Americans would like.

Nevertheless, Japanese and Swedish factory building technology can be readily adapted to suit American demands. Swedish Wooden House (New York), which imports and builds Swedish homes, adapts a design for the U.S. market by converting three Swedish-size bedrooms into a master bedroom plus bath. The company had immediate success with a 17-home resort community built in Sugarbush, Vt., in 1982, and is currently building 100 more homes at various U.S. sites. Skanco Sharon-Foxboro Development plans to construct 220 houses and 345 condominiums during the next five years in the Boston suburb of Sharon, Mass. Built by Myresjohus in Sweden, the units will sell for $190,000 to $325,000. At least a dozen other companies are importing Swedish manufactured homes.

Foreign-built houses are unlikely to flood the country any time soon, however. At current capacity, according to Kando, Sweden could produce at most 20,000 houses a year for export, not enough to dent the U.S. market of almost 2 million units. Meeting domestic demand will keep the Japanese busy for a few years as well. The Japanese already export homes to China and South Korea but do not intend to market the houses here, says Carlson. Yet both the Japanese and the Swedes are interested in setting up joint ventures, enabling the American partner to manufacture houses locally using the foreign technology. □

Kevin Finneran is Washington correspondent for HIGH TECHNOLOGY.

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COMPUTING IN GROUPS

Network software will speed up team projects

Traditionally, microcomputers have supported a single user, and the only method of sharing information and ideas among users has been to physically move a floppy disk from one micro to another. But because a good deal of work in most offices is done by small groups whose members function interactively, new software is being developed to increase the productivity of such groups. This type of computing is so new that it doesn't have a clear name yet; interpersonal computing, work-group computing, computer-supported groups, group decision support systems, and even more awkward names have been proposed.

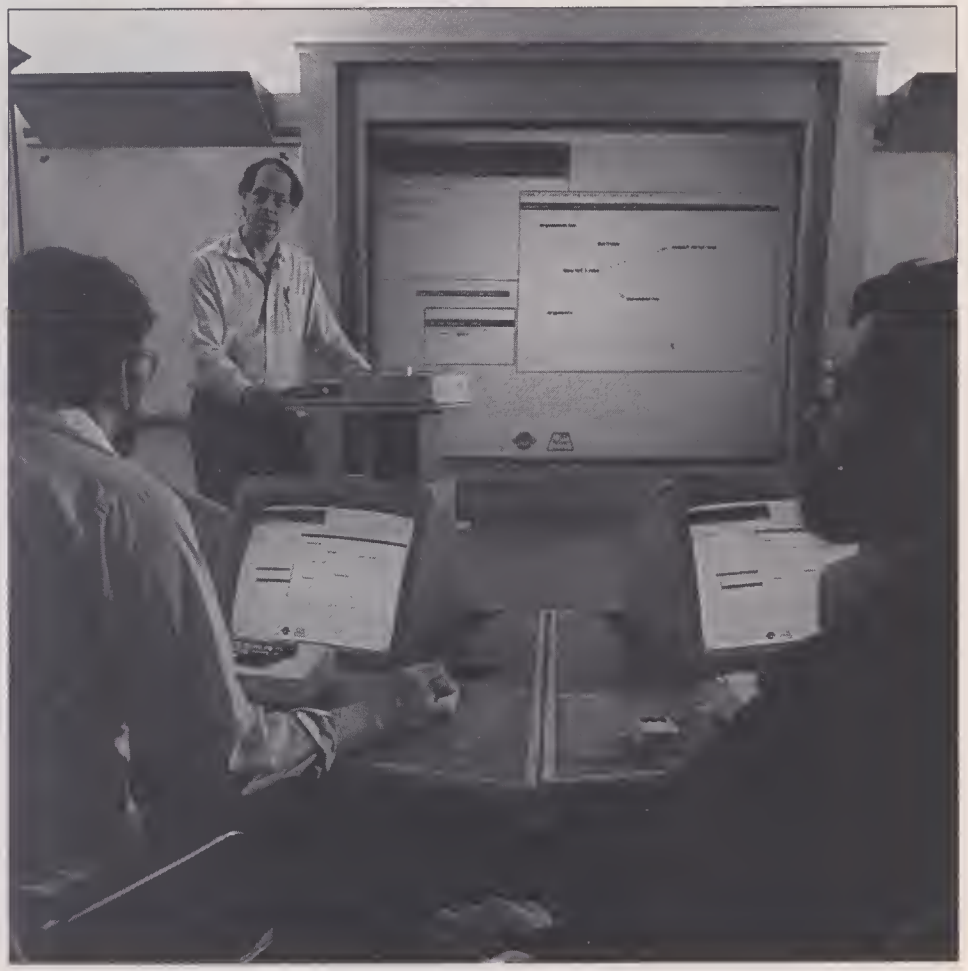
Research into interpersonal computing dates back to development work in the 1960s started by computer scientist Douglas Engelbardt at SRI International in Menlo Park, Cal. Engelbardt's system, called Augment, was an impressive multimedia information-management system that blended voice, video, and computer data as well as a pioneering user interface. Augment was designed to increase the efficiency and productivity of work groups, but its cost and complexity has put it beyond the realm of commercial applications until today.

Engelbardt left SRI in the 1970s and continued to develop Augment at McDonnell Douglas's Tymshare division. Although the system was first developed to be used on larger mainframe computers, Engelbardt's group has recently moved many of Augment's functions to IBM PCs as part of a service that can be leased from Tymshare.

"These are not completely new ideas" but rather "a regrouping of existing research," says Robert Johansen, a director of the telecommunications and computing project at the Institute for the Future (Menlo Park, Cal.). He believes that the recent trend toward distributing computer power from a central facility to desktop computers is starting a move back to a computing model somewhere between a micro and a minicomputer.

Commercial PC software that offers some features of Augment has begun to appear, spurred by the proliferation of local-area networks for microcomputers. Bill Krause, president of local-area network manufacturer 3Com, believes that the next software program to equal the success of Lotus 1-2-3 will be a network application. Krause argues that although there is now only one personal computer for every six office workers, new network software applications will blossom when the number of computers doubles.

At its simplest level, interpersonal computing can supply familiar software applications such as multiuser databases and network electronic mail. Already, major PC software publishers like Ashton-Tate and Microrim have introduced local-area network versions of their database management programs. But these are simply



Xerox's Colab, designed for work groups, features a central electronic blackboard and interactive workstations for participants.

by John Markoff

microcomputer versions of applications already available on mainframes and minicomputers; several users who work independently might share a database.

New applications that will arise as PC networks proliferate include coauthoring systems, real-time conferencing, scheduling, screen sharing, voice annotating of documents, outline processing, and even elaborate multiplayer games.

The first widely available local-area network software packages are electronic mail programs that permit users to send messages and documents. For MS-DOS–based local-area networks, PCC Systems (Palo Alto, Cal.) offers cc:Mail and cc:Mail for Modems. In these programs, one personal computer acts as a central mail server. The modem version allows remote PCs to communicate with a home office or a local-area network.

Other programs permit on-line information sharing by linking two PCs to display an identical screen image. Carbon Copy and cc:Share do this by giving only one user access to the application program at a time; the other user must ask for control to make changes on the screen.

A more elaborate version of this class of software, Optel's Telewriter 3 PC, combines a control and writing tablet with software that transfers color video images captured from a computer display and a high-speed modem. The IBM PC–based system, comarketed by AT&T, offers teleconferencing with an electronic blackboard at each location; users enter commands with a set of buttons on the tablet that also serves as an interactive pointing and drawing instrument. The Telewriter can also extend beyond simple PC-to-PC communications. Using phone company–supplied conferencing lines, it can support simultaneous multipoint communications to as many as 59 different PCs. The program resides in memory on an IBM PC at the same time as a principal application such as a spreadsheet or chart, so it can capture and transmit screens from that application. A spreadsheet screen takes 40 seconds to transmit; a video image takes three minutes.

Another obvious class of interpersonal computer software will be scheduling and planning programs that permit groups of workers to coordinate their activities more productively. Conetic Systems, for example, is now developing an automatic scheduling feature for its Higgins office planning program. The system, which will run on 3Com and Novell local-area networks, will let users set up meetings by directing the program to find available times in the calendars of other users in a network.

The leading laboratory for interpersonal computing is Xerox's Palo Alto Research Center (PARC), whose pioneering research in the 1960s and 1970s led to the personal computer technology that is now commercially available in graphical user interfaces now found in Microsoft Windows and the Apple Macintosh. John Seely Brown, director of PARC's Intelligent Systems Lab (ISL), sees interpersonal software as the technological equivalent of the blackboard, creating an electronic environment to help "people's ideas rub up against each other."

During the past two years, ISL researchers have designed a system called Colab, which has been set up in a special room. Up to eight participants sit before powerful personal workstations, each with a high-resolution screen and a pointing device. An "electern" for the group leader is outfitted with a workstation and a 4 × 6–foot electronic chalkboard called a liveboard, created by a high-resolution video projector. A laser pointing device for the liveboard follows participants' fingers on the touch-sensitive workstation screens.

Each workstation screen has a display window that contains a common electronic workspace for the entire group as well as private work areas. Participants can specify that an item may be modified or deleted by other participants, or protect it from change. Windows can also be opened to support pro and con arguments that can then be sorted according to their assumptions, merits, or impact on related proposals. Private windows permit note taking.

A computer-supported group need not work in the same room or even in the same city. PARC researchers in Palo Alto have linked work groups with a Xerox research laboratory in Portland, Ore., some 600 miles away. The two centers are bound together by video and audio links as well as a high-speed, 56-kilobit digital connection that ties together Ethernet local-area networks at each location.

Obviously, the potential of interpersonal computing is only beginning to be realized. Networked personal computers will ultimately cut the need for meetings, reduce business travel, and automate many routine aspects of modern business.

However, major hurdles remain. In hardware, present computer networks have nowhere near the penetration of the telephone network, and the bulk of micros on desks lack the computing horsepower to perform these tasks well. And network software, says Johansen, has yet to be designed with enough "grace" to be suitable for the typical computer user.

Sophisticated interpersonal software can also create more problems than it solves unless the participants have a clear understanding of how their group works and how to apply the technology. "If you just add the technology, it's not going to do anything," says Tony Wolff, a Santa Rosa, Cal., computer industry consultant who specializes in corporate communications. "You need to create technology that matches the function of a group." □

Companies

Conetic Systems, 1470 Doolittle Dr., San Leandro, CA 94577, (415) 430–8875

Meridian Technology (Carbon Copy), 1101 Dove St., Suite 120, Newport, CA 92660, (714) 476–2224

Optel, 322 8th Ave., New York, NY 10001, (212) 741–9000

PCC Systems, 400 California Ave., #201, Palo Alto, CA 94306, (415) 321–0430

Xerox Palo Alto Research Center, 3333 Coyote Hill Rd., Palo Alto, CA 94304, (415) 494–4000

John Markoff is a technology writer who covers Silicon Valley for the San Francisco Examiner.

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PHONE SECURITY FOR THE REST OF US

Desktop units tap the National Security Agency's voice encryption know-how

You worry that a business competitor might be eavesdropping on your long-distance calls, and you wonder how you can secure your phone system. Help is about to come from an unexpected source—the Defense Department's National Security Agency (NSA). In July the agency awarded contracts to three companies—AT&T Technology Systems (Greensboro, N.C.), Motorola (Schaumburg, Ill.), and RCA Aerospace and Defense (Camden, N.J.)—to produce a new generation of secure telephones it has developed. Although initial production will go to the Defense Department and other government agencies that need to discuss highly classified material via telephone, a pioneering agreement between NSA and the three suppliers ensures that similar phones will be available next year to any individual in the U.S. willing to pay the estimated $2500 price tag and who agrees not to sell the device for export.

Part of the stimulus for development of the product is the ease of intercepting calls. Approximately 90% of all U.S. long-distance telephone conversations take place via satellite and/or terrestrial microwave link—and each one of those calls is vulnerable to eavesdropping. Every small parabolic antenna set up in a backyard demonstrates how easy it is to listen in on satellite communications (in this case, television programs). And it would require only a small number of agents in strategically located buildings to intercept communications carried over terrestrial microwave links.

Government agencies already have the means to secure their phone calls, in the form of the STU-2 (for "secure telephone unit") scrambler. But this device is cumbersome, complex, and expensive. It must be housed in a safe-like cabinet with a combination lock, and must be secured whenever the authorized user is not present. It requires two separate telephone lines to enable both parties to talk and listen simultaneously. And users must make three separate calls to set up a secure telephone conversation—one to obtain a scramble code assignment, and the other two to establish conversation in each direction. In addition, the STU-2 costs the hefty sum of about $15,000.

By contrast, the new STU-3 is barely larger than a conventional telephone handset and can be installed simply by plugging it into a conventional telephone jack. To make calls in its secure mode, an authorized user merely inserts a small plastic key, slightly larger than a house key. (When the key is not in the handset, anyone can use the STU-3 as a conventional telephone.) Secure calls purportedly remain untappable because every communications link-up be-

by Philip J. Klass

The new STU-3 phone (bottom) contains in a single handset all the elements necessary to make secure calls. The older STU-2 (top) required a safelike cabinet with cumbersome electronics to achieve the same effect.

tween two STU-3 telephones uses a different, randomly selected code to scramble and descramble voice and data signals—a code selected seconds before the conversation begins. NSA refuses to reveal details of the STU-3's technology, beyond the fact that it relies on highly secure encryption algorithms that the agency has developed.

The agency has, however, given its three suppliers the freedom to offer any user-convenience features they wish, in order to make their own units more attractive to commercial customers. The RCA model, for example, will provide speed dialing of up to 20 stored telephone numbers, as well as a speaker-phone mode for nonsecure conversations. The AT&T model is expected to offer 10 prestorable numbers for speed dialing and will operate at either of two data rates: 2.4 kilobits per second or 4.8 kilobits per second. The higher rate gives a better voice quality and reduces the time that two handsets take to select a scramble-code, from about eight seconds to around four seconds, but it requires a higher-quality phone line. The initial Motorola deskset, a no-frills version, will probably be slightly smaller than the AT&T and RCA models. All the STU-3s will be able to transmit data securely at a rate of 2400 baud, suitable for moderate amounts of hard-copy information.

The idea of exploiting the forces of economic competition to market the equipment came from Walter Deeley, NSA's deputy director for communications security before his recent retirement. Deeley recognized that meeting his objective of "buttoning up U.S. voice communications by the end of this decade" would require a drastic reduction in the cost, size, and complexity of secure telephone equipment. That meant creating a market for many more units than the government and its contractors would purchase. Originally, the agency projected a market of about 200,000 units for government and defense contractors, with another 300,000 units for government users who need to discuss sensitive but unclassified information. But the agency also estimated a demand for roughly 600,000 units from the private sector—companies concerned enough about industrial espionage to take the opportunity to buy relatively inexpensive secure phones. That figure may prove conservative. Nicholas Piazzola, who heads the NSA's Future Secure Telephone System Development program office, now estimates that the private-sector market could amount to more than a million units if the price falls to about $2000.

Piazzola's group developed the initial concept of the STU-3 in the early 1980s, and submitted it to AT&T's Bell Laboratories for comments on its feasibility in August 1983. Bell Labs endorsed the concept, and in the spring of 1985 NSA selected AT&T, Motorola, and RCA to proceed with design and production, specifying delivery of the first prototypes by June 1986. Each contractor had to agree to tool up to produce 10,000 units per month and to make the first production units available in April 1987, according to Piazzola. Each contract amounted to about $15 million, although Motorola received slightly more to underwrite the cost of a mobile cellular radio version of the STU-3. RCA also contracted to design an STU-3 for military command and control centers, with a provision to enable higher-priority military users to interrupt lower-priority calls.

To maximize production economics, the units destined for government and commercial customers will be almost identical. The units' plastic security keys, however, will differ according to the type of user. The read-only, electrically reprogrammable memories for both types of key will store the user's identity and organization. The keys of government users will also contain the owner's level of security clearance. When a call is placed, the information contained on each party's key will be displayed on the other party's handset.

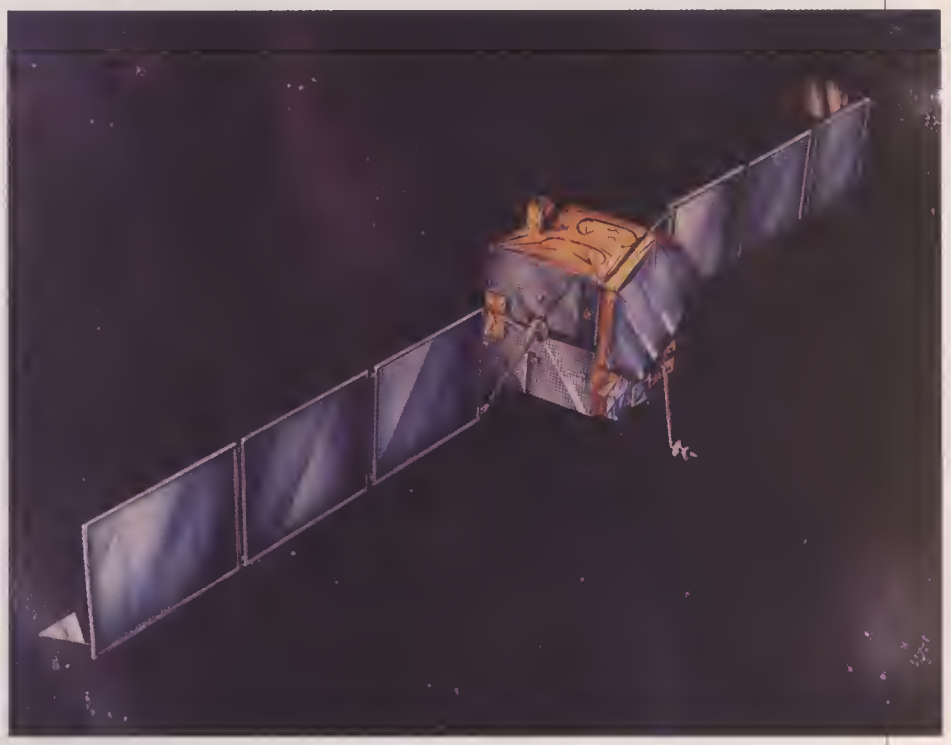
NSA is expected to produce keys for government users, while GTE, one of the unsuccessful contenders for the STU-3 handset contract, is expected to manufacture keys for the general public. To guarantee continued security, government users will be able to reprogram their keys' memories periodically, perhaps annually, by calling NSA.

NSA's understandable desire for security accounts for its requirement that commercial buyers guarantee not to export their STU-3s. Given the complexity and randomness of the coding, it is unlikely that foreign governments could use pirated units to develop a way of listening in on STU-3 conversations. But NSA wants to minimize the risk by constraining export sales as much as possible. □

Philip J. Klass has covered aerospace and defense avionics for three decades at Aviation Week and Space Technology.

SATELLITES TO AID AIR TRAFFIC CONTROL

Space-based tracking will make ocean routes safer



Inmarsat-2, scheduled for launch in 1988, will carry transponders for both aeronautical and maritime service. Inmarsat estimates that a global network of the satellites, providing worldwide air traffic control and aircraft telecommunications, will cost almost $1 billion.

Although few airline passengers realize it, the air traffic control (ATC) techniques applied to transoceanic journeys are 25 years behind those used over land. Instead of using data from ground-based radars, air traffic controllers responsible for aircraft over water must rely on periodic position reports from flight crews, radioed over a transmission band that can often prove unreliable. Thus, controllers must assign a much larger block of airspace as a safety cushion around aircraft making transoceanic flights—a separation of 60 nautical miles, versus 30 nautical miles for overland flights. As a result, crews on transoceanic trips—particularly the crowded North Atlantic routes—may face the choice between flying at altitudes that are less than optimal for speed and fuel economy, and delaying their departures to obtain the best cruising altitudes.

A new type of satellite system, due to go into orbit in two years, promises to overcome these problems. The system, known as AvSat (for "aviation satellite"), consists of a communications satellite transponder that operates in L band frequencies assigned to aeronautical operations (1544–59 megahertz for the uplink and 1645–60 MHz for the downlink). Three AvSats appropriately spaced in geosynchronous orbits above the equator could provide reliable air–ground communications for all aircraft flying between 75° north and 75° south latitude. (For planes above those latitudes, the earth's curvature blocks the line of sight to geosynchronous satellites.) In addition, a network of AvSats could provide air traffic controllers with frequent automatic reports on the position and barometric altitude of each suitably equipped aircraft under their control. If an aircraft encountered severe turbulence, for example, the flight crew could quickly request a different altitude, and the controller could promptly assess the potential for conflict with other aircraft.

United Airlines is especially eager to introduce AvSat data communications service in its Pacific operations, recently expanded by United's acquisition of Pan American's routes. The carrier could use the service to maintain reliable communications with aircraft during their long flights. Then, if a plane needed special maintenance when it arrived at a Pacific destination, the required personnel and replacement equipment could be available when it landed, to ensure a speedy turnaround.

Initially, AvSats will enable aircraft to report their positions through a technique called automatic dependent surveillance. At regular intervals—perhaps once every few minutes—each aircraft equipped for AvSat service will automatically transmit a brief message via satellite giving the aircraft's identity, latitude, longitude, altitude, and perhaps, if enough capacity is available, compass heading. The information will come directly from the aircraft's on-board inertial navigation system and its air data computer, which determines the aircraft's barometric altitude.

By late in this decade, when the new satellite-based Navstar/Global Positioning System becomes fully operational, aircraft will be able to determine and report their position far more accurately than with current inertial systems. This will enable controllers to monitor oceanic traffic more accurately than they do today on overland routes using ground radars. Although Navstar was developed by the Defense Department for military users, civil and foreign aircraft can use

by Philip J. Klass

INMARSAT

its signals with only modest loss of accuracy (HIGH TECHNOLOGY, July/Aug. 1982, p. 61). The USSR plans to deploy a similar system, called Glonass (global navigation satellite system), but whether its signals will be available for civilian users is not known.

An alternative method would use AvSats to carry out surveillance independently of an aircraft's on-board navigation system, using the time delay between aircraft signals routed via two different satellites. But this method demands that both satellites be in the aircraft's line of sight, and hence requires twice as many AvSats. In fact, specialists at the International Civil Aviation Organization (ICAO) contend that the single-satellite approach, automatic dependent surveillance, should be implemented first, because it is less costly.

The concept of automatic dependent surveillance underwent its first feasibility demonstration in August 1985. Controllers tracked a Sabreliner business aircraft built by Rockwell International (Los Angeles), outfitted with a receiver for Navstar data and an experimental transmitter/receiver. The plane communicated with an AvSat-type satellite, hovering over the Atlantic, operated by the International Maritime Satellite Organization (Inmarsat). The test showed that the system worked even with very small antennas aboard the aircraft and at high latitudes at which the satellite appeared low above the horizon.

Inmarsat, a consortium headquartered in London and jointly owned by more than 40 maritime nations, operates a global network of satellites that provide voice and data communications for shipping companies and other maritime users. Because the frequency bands officially assigned for maritime satellite service (1535–44 and 1636–45 MHz) are next to the band authorized for aeronautical service, and because Inmarsat is anxious to expand its market, the organization decided to design its next generation of satellites to operate at both aeronautical and maritime frequencies. British Aerospace (London) is now building the first of these new-generation Inmarsat-2 satellites, with Hughes Aircraft (Los Angeles) as a principal subcontractor. The first launch is scheduled for 1988, with a second to follow in 1990.

Meanwhile, Inmarsat is encouraging other experiments, which will use existing satellites to demonstrate the potential of an AvSat communications link. For example, British Airways is outfitting three of its Boeing 747 jetliners to offer passengers in-flight radiotelephone service via an Inmarsat satellite. Also planning tests of two-way communication between aircraft and ground stations is Société Internationale de Télécommunications Aeronautique (SITA), an organization in Neuilly, France, that provides global telecommunications services to nearly 250 different airlines.

To assure the near-term availability of suitable airborne AvSat equipment, Inmarsat will soon select a company to design and build prototype hardware, with delivery scheduled for next spring. The contract calls for two different types of avionics equipment. The less expensive will provide only data communications required for automatic dependent surveillance and the exchange of such routine air-to-ground messages as requests for a different altitude. The more expensive type will also provide two or more voice channels. Such expanded capacity will require aircraft to be equipped with a larger, more costly phased array antenna, whose beam can be electronically pointed at Inmarsat-2.

A new satellite system promises to improve global air traffic control.

More recently, a request for industry bids for an airborne AvSat terminal was issued by Aeronautical Radio Inc. (Arinc), an Annapolis, Md., company owned by U.S. airlines, which it provides with centralized communications sevices. Although the Arinc specifications differ somewhat from those of Inmarsat, they also seek basic equipment to provide data communications that can be upgraded to provide voice service at the user's option.

In anticipation of the time, perhaps early in the next century, when AvSats could replace terrestrial communications and radar surveillance for U.S. domestic service, the Federal Aviation Administration earlier asked the Radio Technical Commission for Aeronautics to prepare a conceptual blueprint for a next-generation air traffic control system. RTCA's final report, due soon, closely parallels the current views of the ICAO specialists.

ICAO's final decision on a transoceanic ATC system will eventually have important implications for international travelers who fly to less developed nations in Africa, Asia, and South America that cannot afford many ground-based facilities approved by ICAO. Once space-based ATC systems come into use for both oceanic and overland service, aircraft will be able to fly anywhere in the world using a single set of standard avionics that will provide the same level of performance and reliability wherever they are.

One unresolved issue is ownership of AvSats. Should a single agency own and operate a global network of the satellites, or should several regional agencies, independently serving the Western Hemisphere, Western Europe and Africa, and other geographic groupings, do the job? Inmarsat believes that it is the logical agency to operate a global AvSat system, as an extension of its worldwide maritime service. Separate transponders operating at maritime and aviation frequencies would share spacecraft, according to Olof Lundberg, director-general of Inmarsat.

That could ease perhaps the biggest obstacle to early implementation of AvSat service—the high cost of its introduction. Inmarsat estimates that the cost of setting up its new Inmarsat-2 global network will be nearly $1 billion. By picking up that tab, says Lundberg, Inmarsat will enable financially pressed airline companies to plug into AvSat service without any major investment beyond the $100,000–$200,000 per plane necessary to outfit their aircraft with AvSat avionics. □

Philip J. Klass has covered aerospace and defense avionics for three decades at Aviation Week & Space Technology.

TWO-EYED ROBOTS

Dual cameras will allow faster assembly without the drawbacks of current 3-D vision

The era of two-eyed industrial robots has begun, as researchers in the U.S. and Canada unveil machine vision systems that use two video cameras to perceive depth the way humans do. While three-dimensional machine vision systems have so far been used primarily for product inspection in factories, the new systems promise to greatly expand the versatility of factory robots. Stereoscopic vision augments high-speed robotic assembly, since a detailed 3-D map of its surroundings permits a robot to position components faster. It may also be used for guiding fast-moving, self-navigating robot drones.

And because stereoscopic vision enables robots to find parts amid a random, irregular background, the robots can be more effective at tasks like bin sorting; in most current applications, they can select only parts that have been prearranged in a magazine or on an assembly line.

As in human eyesight, stereoscopic machine vision merges two pictures into a single image, calculating depth by measuring the apparent displacement of an object between the two "eyes." Thus the closer the object, the greater its displacement. But until recently, the images of the two cameras could not be brought into registration quickly enough to be practical for industrial use. It's hypothesized that the human brain makes millions of computations, many simultaneously, to construct a comprehensive 3-D image. Serial computers, performing only one task at a time, cannot do that in the fraction of a second necessary for decision making in many industrial processes.

by Daniel Sweeney

Work begun at MIT in the 1970s led Schlumberger Lab research scientist Keith Nishihara to a practical stereoscopic vision system.

JEFFREY COOLIDGE

But two new stereoscopic systems are said to permit rapid depth perception in a typical factory environment. Keith Nishihara, chief researcher in two-eyed vision at Schlumberger Labs in Palo Alto, Cal., says his system is ready for commercialization.

Refining work he did at MIT in the late 1970s, Nishihara speeds up stereo vision by reducing the amount of image analysis needed to register right and left camera shots. Rather than processing full-resolution images, Nishihara's computer program finds patches of uniform light intensity in one image and merges them with identical patches in the other. This abbreviated correlation process cuts computing time enough for industrial applications.

However, the low resolution of the images prevents object identification; the system can tell a robot how far away an object is, but can't determine precisely what it is. Thus Nishihara's system is designed for applications requiring distance measurements only. Tomaso Poggio, a former colleague of Nishihara's at MIT and now a consultant for Thinking Machines (Cambridge, Mass.), is developing parallel processing computer programs that provide high-resolution 3-D by processing the two camera images simulta-

neously, while running other vision subprograms like recognition of an object for which a robot may be searching. However, high-powered computers capable of making such parallel calculations are largely developmental and too expensive for industrial machine vision. Poggio doesn't expect such systems to be widely available for several years.

Meanwhile, a system developed by Automatic Vision (Vancouver, B.C.) for analyzing terrain gradients in aerial photographs is now being offered to industrial users. Advance orders for the vision module, priced around $15,000, should be filled beginning this year, says company president Theodore Hobrough.

Automatic Vision takes a different approach to stereoscopic depth perception, measuring the voltage-pulse wave forms that represent the image after it is converted to an electrical signal by the video camera. Since two cameras viewing the same image produce identical wave forms, Automatic Vision matches up the waves between right and left cameras and then calculates displacement by measuring the difference in the phase, or timing, of the wave sets.

This system provides high-speed depth perception and the potential for high resolution. But because the basic module computes only the phase difference—the measure of distance—additional software must be used to further process the video image for tasks such as object identification.

Other methods of depth perception are already being used by industry. Most of the current techniques—which find the range, or distance, to an object—project an audio, microwave, or light signal toward an object and receive the reflection at a sensor or sensor array. The simplest ranging systems, such as ones developed by General Motors (Detroit) and the Stanford Research Institute (Palo Alto, Cal.), use a projector and video camera, which are coupled to a computer that determines distance to the object by elementary trigonometric calculations based on readings of the light's path. Ultrasound systems measure the elapsed time between the emission of a sound wave and the reception of its echo at a microphone. Although a sonar method developed by Cochlea (San Jose, Cal.) can detect object contours, most ranging systems calculate distance to an object only; they cannot provide a comprehensive 3-D picture of a work space. What's more, ranging methods require additional 3-D systems to perform other vision functions like pattern recognition or object identification.

Monocular vision systems, using a single video camera, may also be programmed for depth perception, by comparing the apparent size of an object viewed at a distance to its actual size, or the apparent velocity at which it crosses the field of view compared with its actual, known velocity. However, values like actual size and velocity must be preprogrammed into the system, limiting its ability to handle the unexpected.

Another method of depth perception uses colored light projected in bar or grid patterns, with video cameras to pick up the deflection pattern caused by the objects in the light field. By analyzing the amount of deflection, a computer determines an object's depth dimensions. Thus, this "structured light" approach is employed extensively for checking parts. GM uses its Consight method in assembly plants, and Diffracto (Windsor, Ont.) offers another system. The National Bureau of Standards (Gaithersburg, Md.), Stanford Research, and Jet Propulsion Laboratory (Pasadena, Cal.) are also developing systems.

Since inspection tasks account for about 75% of the current industrial vision market, structured light dimensioning has strong market promise, says John Meyer, president of Tech Tran Consultants (Lake Geneva, Wis.). Such noncontact inspection systems, he says, are faster than conventional touch-gauging while remaining relatively low in price.

However, structured light requires dim illumination; a special environment must be provided on the factory floor. Since most other vision systems need bright illumination, they can't be combined with structured light to perform additional vision tasks.

Recognizing this limitation, the Delphi study of machine vision, completed in June by the University of Michigan, identified stereoscopic systems as one of the top vision priorities of U.S. automakers. The report also concluded that stereo vision, necessary for part selection and orientation by robots or other material-handling devices, will reduce the dependence on specialized lighting conditions for 3-D techniques like structured light.

Since they fit well into factory environments and promise both range finding and object identification, stereoscopic systems "have tremendous potential," says Marcia Brooks, a senior analyst at International Data Corp. (Framingham, Mass.). Nevertheless, she warns that prices for such systems must be moderate, and that vendors of stereoscopic and other vision systems must pay closer attention to fitting their products to specific applications. A common fault in the industry so far, she says, has been to assume that off-the-shelf vision systems can be used in a wide array of applications. "You can develop the basic technology," she says, "but then you have to make it *do* something."

If they succeed at this, 3-D vision vendors stand to profit: Meyer of Tech Tran forecasts that 3-D's share of the vision market will grow from its current 10% to about 25% by 1990. At the same time, he says, total machine vision sales will expand by about 40% annually from their current level of about $100 million.

Most 3-D industrial applications will remain in inspection, according to the analysts. Although stereoscopic vision systems will greatly enhance robot guidance, continued sluggish growth in robots will hold back wider use of vision to control them, Brooks says, even as robot makers and vision suppliers become more responsive to the needs of potential customers. But this situation will eventually change. "3-D just hasn't reached its time yet," she says. "It will explode, but that's still several years away." □

Daniel Sweeney is a freelance electronics writer based in Burbank, Cal.

PERSPECTIVES

Two congressmen keep technology policy on the agenda

Despite its potential role in restoring U.S. competitiveness, the development of a comprehensive technology policy has not been a high priority for most members of Congress. But there are two major exceptions.

Congressman Tim Wirth (D-Colo.), the Democratic candidate for senator from Colorado, was among the first members of Congress to raise the issue of a technology policy. As 1982 chairman of the Democratic Special Task Force on Long-Term Economic Policy, Wirth wrote *Rebuilding the Road to Opportunity*, a proposed program to stimulate economic growth by capitalizing on the potential of high technology to revive traditional industries and create new ones. Wirth's report called for policies to increase government support for R&D, stimulate capital formation, reduce the federal deficit, and support education and training.

Democrat Wirth: "The U.S. is being played for a sucker in international trade, and Congress has to pressure the administration to take a stronger position."

Congressman Ed Zschau (R-Cal.), who represents Silicon Valley and is challenging Alan Cranston for a Senate seat, played a similar role for House Republicans. As chairman of the Republican Task Force on High Technology Initiatives, he has published two editions of *Targeting the Process of Innovation*, which offers a Republican high technology policy. Like the Democratic proposals, Zschau's report calls for a commitment to R&D, incentives for risk taking and capital formation, an adequate supply of skilled workers, and expansion of market opportunities through reducing the federal deficit and introducing a tougher trade policy.

Zschau says the approaches of the two parties differ in that the Democrats want to target specific industries for support while the Republicans would target the process of innovation. "The government is not smart enough to pick winners and losers," says Zschau, "but it can create the environment in which the private sector does."

Wirth maintains that the Democrats do not want to pick winners and losers per se, but that they do support a more direct federal role in stimulating innovation and economic growth. Whereas Zschau would place responsibility for improving primary and secondary education completely in the hands of state and local government, for example, Wirth sees a need for federal action and support. Likewise in worker training, Zschau recommends incentives such as tax-exempt Individual Training Accounts that would let workers put aside money to pay for retraining; Wirth supports this, but adds that the government ought to shoulder some of the burden as well. "We have to face up to the cost of retraining," says Wirth. "That's going to be an expensive item, but cheap in the long run. We need the equivalent of a GI bill for workers."

Republican Zschau: "In terms of its impact on jobs and economic growth, a dollar spent on defense is of less value than a dollar spent in the private sector on research."

Although four years have passed since Wirth published his report, he believes that the recommendations are still sound—and still in need of implementation. "The report changed the terms of the debate and opened new policy options," says Wirth, "but the major proposals have not been adopted." An area that Wirth has added to his agenda is trade relations. "The U.S. is being played for a sucker in international trade," he says, "and Congress has to pressure the administration to take a stronger position. The administration pursues the myth that the world is operating under rules of free trade, but wishing for it isn't going to make it happen." Zschau would grant the U.S. Trade Representative more power in dealing with unfair trade practices but is less willing to criticize Reagan administration efforts.

Zschau does disagree with the administration on some issues. He is concerned, for example, that the large share of federal R&D funds going to the military will have a negative effect on the economy. "In terms of its impact on jobs and economic growth, a dollar spent on defense is of less value than a dollar spent in the private sector on research," claims Zschau. "We should be frugal in our allocation of research funds to defense." He also disapproves of the administration's desire to eliminate the Commerce Department's Office of Productivity, Technology and Innovation; to do so, he says, would be "a tragic mistake." Managed by assistant secretary Bruce Merrifield, it is the only office among federal agencies that is devoted to promoting technological competitiveness. Republicans and Democrats recently rallied to support the office, approving funds to continue its operation through fiscal 1986.

BOTTOM: ROGER MILLER

Zschau sees the Republican Task Force on High Technology as a mechanism to coordinate technology policy. He points out that seven of the 14 recommendations from the task force's 1984 report have become law. These include increased government support for civilian basic research, changes in antitrust laws to encourage joint R&D, and several trade enhancement measures. Still, he notes, all of these areas need more attention. "At present," says Zschau, "we have a de facto technology policy—the sum of many separate decisions on such issues as R&D, taxes, and trade." □ ***—Kevin Finneran***

Implants relieve chronic back pain

Thousands of people once afflicted with chronic back pain are now living relatively pain-free because of small, surgically implantable computerized pulse generators that mask pain. The generator's integrated circuitry sends an electrical pulse to the spinal cord, apparently causing the brain to register a tingling sensation instead of pain. Although the generators still face several technical and marketing hurdles, manufacturers claim that the market for the devices may one day surpass that for cardiac pacemakers.

The pulse generator concept has been applied to various medical disorders since 1967, but the new implants owe their existence to recent miniaturization techniques. One popular model—the Itrel Portable Programmer, manufactured by pacemaker pioneer Medtronic (Minneapolis)—is only about 2½ inches long and half an inch thick, and weighs a little more than an ounce. The device is implanted in the stomach area in a simple operation, and two electrical leads are snaked under the skin to the spinal cord.

Slightly more than half the recipients report a dramatic reduction in pain (although side effects commonly include decreased blood flow to the extremities and increased sweating). And pain that is not transmitted by the spinal cord—such as that associated with strokes and head injuries—may be controlled by implanting the leads directly into the brain.

"I see a big future in these devices as they become more sophisticated and easier to use," says neurosurgeon Giancarlo Barolat at Thomas Jefferson University in Philadelphia, who has implanted about 100 of the generators. "They're not causing any damage to the nervous system, and the procedure is reversible."

So far, about 30,000 Americans have received the implants. Medtronic sold about 3000 of the devices during 1985, at an average distributed price of $2000 each. Other manufacturers include Cordis Corp. (Miami), Neuromed (Ft. Lauderdale, Fla.), and Avery Laboratories (Farmingdale, N.Y.).

Researchers claim that chronic, intractable back pain can be relieved either by preventing certain electrical signals from reaching the brain or by "masking" the signals so the brain interprets them as something other than pain. And while the exact mechanism by which the generators relieve pain is still unknown, three theories have been advanced:

- The pulses from the generator reach the brain before the pain signals, in effect superseding them.
- The pulses trigger internal secretions of pain-relieving chemicals such as those presumably responsible for "runner's high."
- The electrical impulses scramble the pain signals to the brain so that pain is felt instead as a tingling in the extremities.

The magnetically activated generator runs on a lithium battery; pulse rate and amplitude are preset on a small desktop programming unit by the physician or the manufacturer's representative. To turn the generator on or off, the patient simply presses a donut-shaped magnet into the skin above the implant.

Despite its simplicity and its effectiveness in many patients, the generator still lacks broad acceptance by physicians. One reason for their reluctance, says Medtronic sales specialist John Williamson, is that "a lot of doctors are very hesitant about putting electronic gear into a patient." Another is the obvious risk associated with implanting the electrodes in the brain or the spinal cord; in fact, only 5–10% of the nations's 3000 neurosurgeons have performed the operation.

Yet another reason is physicians' hypersensitivity to the possibility of malpractice suits. Robert Richardson, chief of the Section of Physiological Neurosurgery at Mt. Sinai Hospital Medical Center in Chicago, asserts that many chronic pain patients are heavily dependent on narcotics and are "litigation-prone."

Nor have manufacturers had an easy time convincing surgeons and cost-conscious hospital administrators to purchase the implants and programmers—packages that can run as high as $6000. Nevertheless, producers hope that a better understanding of how the implants work in the body will lead to broader acceptance by the medical community. That acceptance, moreover, could lead to an entirely new generation of implants: while pain-control generators are the only ones that now have FDA approval, similar devices might one day help treat other disorders—including severe obesity, depression, hearing and vision loss, and seizures—by implanting the leads into various regions of the brain. □ ***—Barry Rosenberg***

Cuban biotechnology aims for fast results

Though cut off politically and economically from the U.S. for the past 25 years, Cuba has set itself an ambitious scientific agenda. Spurred by about 40,000 researchers and support staffers, Cuban research spending of all kinds has about doubled during the past five years, standing now at close to $165 million (slightly more than 1% of the national budget).

"Cuba has no gold or diamonds," says Jose Fernandez Alvarez, minister of education. "We have to use our greatest wealth—our intellects—to substitute for the scarcity of resources."

One intellectual asset, biotechnolo-

LEE LOCKWOOD

Cuba's sugarcane crop and the nation's biotechnology agenda are closely intertwined. Not only are researchers using new genetic engineering techniques to develop disease-resistant sugarcane varieties, but crop byproducts are used to grow yeast as a high-protein food supplement for animals and humans.

gy research, is becoming an increasingly important means of transforming Cuban science into commercial health and agricultural products. Programs now under way include animal vaccines, interferon, biomass conversion, and high-protein food additives. While many of the new products and processes are pegged to domestic applications, some are also being tagged for export as part of Cuba's political plan to provide technical and medical assistance to the third world.

Cuban vaccine researchers recently cloned the toxin gene of the microorganism that causes red water fever, a hemorrhagic disease of cattle. The disease is a major problem in Latin America, and sometimes affects herds in the U.S. "I think this is the first group in the world to isolate this toxin gene," says Alejandro Silva, chief of microbiology at the five-year-old Center for Biological Research (CIB by its Spanish acronym). Studies are now being conducted to determine whether the toxin protein can be used as a vaccine against the disease.

CIB was originally founded to supply Cuban doctors with interferon (derived from human white blood cells) for testing against cancer and viral diseases. Interest in interferon arose in part because of an outbreak of Dengue fever in late 1980 that struck about 300,000 people and killed about 160. Out of desperation, interferon was used in some patients, and is credited with saving the lives of several children.

The protein is also used experimentally by Cuban researchers against a variety of other diseases, including laryngeal papillomatosis (a type of throat tumor), hepatitis B, and certain types of lung cancer.

Cuba is now the world's second largest producer of human-derived interferon (the U.S. and Finland are roughly tied for first) because of the country's extensive blood-donor system; the state-owned pharmaceutical firm, MediCuba, plans to market several forms of interferon around the world. The company also includes genetically engineered interferon in its product line, but commercialization plans are still unclear. "Our interferon work has become a model for immunological research, genetic engineering, monoclonal antibody production, and other developments," says CIB director Manuel Limonta Vidal.

At the National Center for Scientific Research (CNIC), meanwhile, geneticists are working on new methods for improving sugarcane, the nation's most important crop; Cuba produces about 8 million tons of sugar per year, most of which is sold to the Soviet Union. "This work is really still an art," says CNIC's Rodolfo Maribona, who was trained in genetics and protein synthesis in the Soviet Union.

One such method is called somaclonal variation, a process by which cells from a single plant can be induced through hormone manipulation to develop into variants that exhibit new genetic properties. Such properties include disease resistance, salt tolerance, and higher yield. For example, CNIC researchers are creating sugarcane varieties that are resistant to the fungal disease caused by the organism *H. sacchari.* Cultured plant cells are first subjected to the purified fungal toxin protein; of the variants grown from the culture, some exhibit unusual resistance to the fungus. Moreover, the resistance trait appears to be stable in the adult plants and in subsequent generations, according to Maribona, and one variant has been immune to the disease for three years.

But refined sugar is not the only foodstuff obtained from the sugarcane. Up to 100,000 tons of poultry and pig feed is produced annually by growing yeast on sugarcane byproducts. Such yeast products are too rich in nucleic acids for human consumption; however, yeast from which the acids have been extracted is now being safety-tested. Within five years, Cuba expects to use such yeast as a high-protein human food supplement.

The Cubans also make nonfood products from the sugarcane residue. Several factories produce fiberboard and paper from the plant fibers, for example, and the wax of the cane is used for coating fresh fruits and as a base for cosmetics. Scientists at the University of Havana are studying the wax as a possible raw material for drug and fine chemical production.

Because of political and economic factors, Cuba's immediate scientific goals are obviously somewhat different from those of the United States. In general, the nation's tasks are more pragmatic and are geared to a faster payoff. Still, many Cuban programs seem to parallel those of biotech companies in the U.S. and Western Europe. On a recent visit to CIB, in fact, one American geneticist commented: "It's just like a small gene-cloning company." That assessment may reflect both the limitations and strengths of Cuba's biotechnology agenda. □

—Jeffrey L. Fox and Julie Ann Miller

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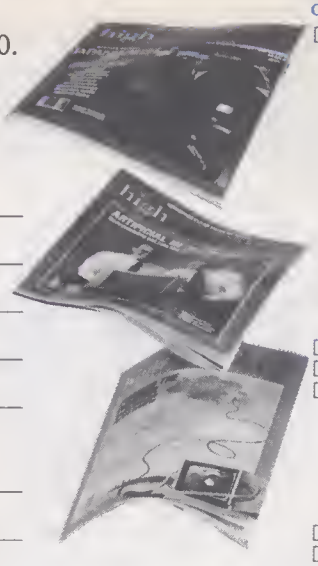

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TECHSTARTS

Exovir:
BIOTECH SALVES

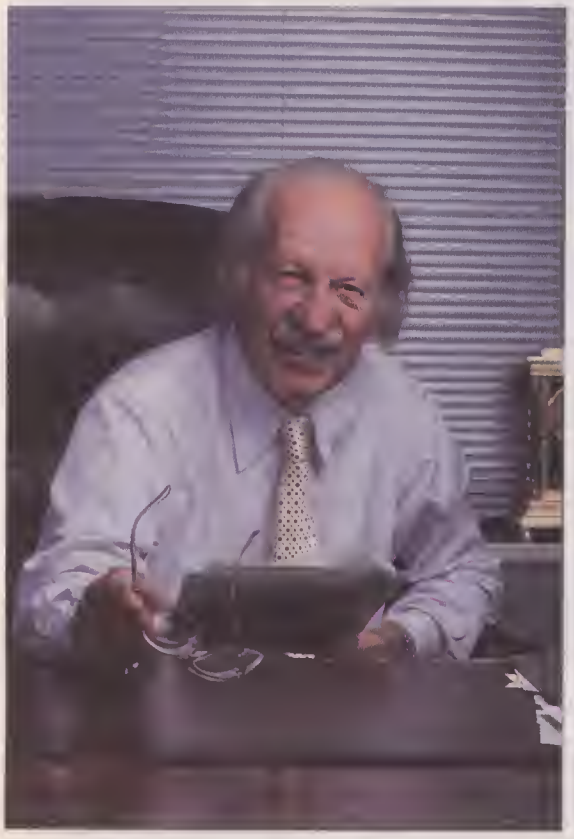
While most commercially available biotechnology-based drugs are either injected into a patient's bloodstream or taken orally, Exovir has developed a topical treatment made of a surface-acting gel combined with interferon. The substance is being tested for use against viral skin diseases, including oral and genital herpes. The company is also evaluating other blood proteins for possible combination with the proprietary gel to use in the treatment of wounds, and it is conducting research jointly with Genentech to combine the gel with several anticancer drugs. Exovir's products will compete primarily with topical drug delivery systems, such as membrane-based adhesive patches for controlled release of substances.

Financing: $495,000 from a March 1983 private stock placement. $3.89 million in net proceeds from an October 1983 public offering of 1.15 million shares.

Management: Maxwell M. Powell (founder, chairman, and CEO) was president and director of Life Sciences, a biomedical R&D company. Richard D. Glaser (president and COO) was VP in charge of biomedical R&D for the Specialty Materials Group of AMF. Fred Rapp (scientific adviser) is chairman of the department of microbiology at Pennsylvania State University's College of Medicine.

Location: 111 Great Neck Rd., Great Neck, NY 11021, (516) 466–2110.

Founded: May 1981.



Exovir expects its antiviral salve to be used in the treatment of skin diseases, says Maxwell M. Powell, chairman and CEO.

RAY ELLIS

AI Technologies:
WORKSTATIONS WITH MAINFRAME SPEED

Although desktop computers started out as fairly rudimentary machines, they've steadily increased both their horsepower and versatility. The desktop machine under development at AI Technologies will match a mainframe's computing speed, claims the company, by processing more than 40 million instructions per second. Called the Cyclone, the machine is based on a proprietary 32-bit microprocessor that combines design features of reduced-instruction-set computers with on-chip circuitry for floating-point mathematical calculations. Scheduled for commercial introduction in 1988, the Cyclone will be aimed at engineering number-crunching and artificial intelligence applications such as expert systems, which require sifting vast amounts of data. Competitors will be engineering workstation makers ranging from Sun Microsystems to Digital Equipment Corp.

Financing: $1.3 million from company principals.

Management: Paul Schroeder (president) and David Wooten (VP of product development) came from chip maker Inmos International, where Schroeder was COO and Wooten was a design engineer. Timothy Coutts (VP of finance and administration) headed a department for emerging business services at accounting firm Deloitte Haskins and Sells.

Location: 1041 Elkton Dr., Colorado Springs, CO 80907, (303) 590–1886.

Founded: May 1983.

Ecco Industries:
VOICES THAT OPEN DOORS

The latest wrinkle in security systems that automatically allow authorized personnel to enter restricted areas is biometrics—identification through unique personal features such as fingerprints. Ecco Industries' VoiceKey System is based on "voiceprints," individual accoustic patterns that the company claims are unaffected by colds and can't be reproduced by ordinary tape recordings. At the heart of the system is an IBM-compatible PC containing a proprietary circuit board that runs the voice-verification algorithm; a telephone handset and keypad are installed at each entry point. The company is aiming the system at government, military, computer, and healthcare facilities. Competitors include other biometrics companies such as Fingermatrix, as well as makers of sophisticated conventional security systems, such as Honeywell.

Financing: $3 million in venture capital from individual investors.

Management: Heath Paley (president) headed the Maine Woods Shoe division of Bennett Industries. Michael Backler (VP of marketing and sales) was VP of marketing for Kurzweil Computer Products. Thomas Denker (director of software development) was a system designer for Motorola Microsystems. Bruce Smith (director of hardware development) was director of engineering for International Teletron.

Location: 130 Centre St., Danvers, MA 01923, (617) 777–7750.

Founded: August 1983.

EYE SURGERY PRODUCTS SEE STEADY GROWTH

Lens implants and related devices are now a billion-dollar market

In recent years, significant advances in eye surgery have been particularly helpful to the one in every 19 Americans who suffers from a defect that cannot be totally corrected with eyeglasses or contact lenses. The 1986 U.S. market for ophthalmic devices—which includes intraocular lenses (IOLs) and refractive surgery equipment but excludes vision-care products such as eyeglasses—is estimated at well over $1 billion. Growth is being spurred by the needs of an increasingly elderly population, eye strain caused by increased amounts of time spent watching TV and working at video display terminals, and patients' general refusal to accept reduced vision as a state of life.

An IOL is implanted in a brief procedure following surgery to remove cataracts, which impede the the transmission of light through the inner lens of the eye to the retina. If uncorrected, this condition, which primarily afflicts the elderly, leads to functional blindness. In general, replacing the inner lens with an IOL rapidly restores near-normal eyesight. Currently, 95% of the 1.1 million new cataract surgery patients in the U.S. receive an IOL. One significant development with IOLs is the emergence of soft, foldable lenses made of silicone rubber and other biocompatible materials. Designed to cause less trauma to the eye during and following their implantation, these lightweight IOLs are expected to largely replace hard IOLs in the next decade.

Refractive surgery modifies the anterior corneal curvature to improve the patient's natural vision, thereby reducing or eliminating the need for glasses or contact lenses. Devices used in different types of refractive surgery include instruments to make precise, controlled-depth incisions in the cornea to correct mild nearsightedness, and the microkeratome, an instrument that can shave thin surface tissues from the cornea to correct more severe refractive errors.

An ultraviolet-absorbing interocular lens, made by Optical Radiation, replaces a human lens after a cataract operation.

Many companies are active in the ophthalmic surgical market, including Johnson & Johnson, SmithKline Beckman, 3M, and Pharmacia. Two independent public companies—Coopervision (Menlo Park, Cal.) and Optical Radiation (Azusa, Cal.)—should be particularly attractive to investors in view of their leading-edge technology and aggressive marketing strategies.

Coopervision (NYSE: EYE) is one of the world's largest and most diversified ophthalmic device companies, with products in virtually every ophthalmic growth arena. Coopervision has made a number of moves that have brought it the largest share (an estimated 22%) of the IOL market. The acquisition of Cilco gave the company access to a viscoelastic solution used to protect the cornea during IOL implants; this material represents a potential $100 million worldwide market. Coopervision has also obtained exclusive licensing rights from Staar Surgical for an IOL made from pure silicone and has introduced the Novaflex series of silicone lenses, which reduce pressure on delicate ocular tissue following the implant. The company's Smartknife, a scalpel connected to a laser calibration device that provides a digital readout of blade depth in microns, could eventually help bring robotics into refractive surgery.

Company revenues in 1985 were $331 million, with profits of $35.2 million and $1.69 earnings per share. Taking into account its recent acquisitions, Coopervision's consolidated revenues this year should reach $430 million. However, integrating its ophthalmic acquisitions will reduce its earnings; profits should drop to zero. In 1987, earnings should increase to a projected $45 million and $2.07 per share, based on revenues of about $480 million.

Optical Radiation (NASDAQ: ORCO) has been a leader in IOLs that filter out ultraviolet rays, which can cause long-term harm to the eyes. The company is also on the forefront of several other IOL developments. One is a type of lens that allows the use of laser treatment to remove secondary cataracts following implantation, without damaging the lens; another is dehydrated IOLs—currently undergoing animal trials—which can swell from 3.2 to 6 millimeters after implantation, enabling the surgeon to make a much smaller incision. In the area of refractive surgery, Optical Radiation has introduced the Oracle, a keratometer that performs real-time mapping of the cornea surface for fitting lenses and that calculates corneal shape modifications to be achieved in the operation.

Profits for fiscal 1985 were $12.5 million, or $1.50 per share, based on income of $96.5 million. These figures may decline in 1986, with estimated income at $96 million and $1 earnings per share, primarily because of an operating loss at the company's Omega Optical subsidiary, along with continuing high expenses for the introduction of new lens product lines. Earnings should pick up again next year, now that production problems with Omega's Lite Style eyeglass lenses have been solved. □

by Pieter Halter

Pieter Halter is president of Biomedical Business International (Tustin, Cal.), a medical consulting and market research firm.

WHEN

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